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Survey of Ethylene Dichloride Emission Sources

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The potential health impact of nationwide ethylene dichloride emissions is being investigated. This document contains information on the sources of ethylene dichloride emissions, current emission levels, control methods that could be used to reduce ethylene dichloride emissions, and cost estimates for employing controls.

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Survey of Ethylene Dichloride Emission Sources

Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

December 1984

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TABLE OF CONTENTS

Page

Preface ii

Table of Contents iii

List of Tables vi

List of Figures viii

1. INTRODUCTION AND SUMMARY 1-1

1.1 INTRODUCTION 1-1

1.2 SUMMARY 1-1

1.2.1 Industry Description 1-1
1.2.2 Emission and Cost-Effectiveness Data 1-2
1.2.3 Regulatory Requirements 1-4

2. CHEMICAL PLANTS 2-1

2.1 ETHYLENE DICHLORIDE PRODUCTION AND USE 2-1

2.1.1 Ethylene Dichloride Production 2-1
2.1.2 Vinyl Chloride Monomer Production 2-2
2.1.3 Ethyl Chloride Production 2-3
2.1.4 Methyl Chloroform Production 2-3
2.1.5 Ethyleneamines Production 2-4
2.1.6 Perchloroethylene and Trichloroethylene Production 2-5

2.2 PROCESS VENTS 2-6

2.2.1 Current Controls and Emissions 2-6
2.2.2 Additional Controls 2-7

2.3 FUGITIVE SOURCES 2-8

2.3.1 Current Controls and Emissions 2-8
2.3.2 Additional Controls 2-9

2.4 SECONDARY EMISSIONS 2-9

2.4.1 Emission Sources 2-9
2.4.2 Current Controls and Emissions 2-10
2.4.3 Additional Controls 2-10

TABLE OF CONTENTS (continued)

Page

2.5 STORAGE TANKS 2-11

2.5.1 Current EDC Storage Patterns 2-11
2.5.2 Current Controls and Emissions 2-16
2.5.3 Additional Emission Control Techniques 2-17

2.6 TANK TRUCK/RAIL CAR/BARGE LOADING 2-20

2.6.1 Emission Sources 2-20
2.6.2 Current Controls and Emissions 2-21
2.6.3 Additional Controls 2-22

2.7 REFERENCES 2-68

3. PUBLICLY OWNED TREATMENT WORKS 3-1

3.1 ETHYLENE DICHLORIDE SOURCES AND EMISSIONS 3-1

3.2 REFERENCES 3-7

4. PHARMACEUTICAL MANUFACTURING PLANTS 4-1

4.1 ETHYLENE DICHLORIDE SOURCES AND EMISSIONS 4-1

4.2 REFERENCES 4-4

5. LEAD SCAVENGER BLENDING FACILITIES 5-1

5.1 ETHYLENE DICHLORIDE USE AND EMISSIONS 5-1

5.2 REFERENCES 5-14

6. MISCELLANEOUS USES AND EMISSION SOURCES 6-1

6.1 ETHYLENE DICHLORIDE SOURCES AND EMISSIONS 6-1

6.1.1 Paints, Coatings, and Adhesives 6-1
6.1.2 Extraction Solvent 6-2
6.1.3 Cleaning Solvent 6-2
6.1.4 Polysulfide Rubber Production 6-3
6.1.5 Grain Fumigant 6-3
6.1.6 Liquid Pesticide Formulations 6-4
6.1.7 Miscellaneous EDC Uses 6-5
6.1.8 Volatilization From Waste Treatment, Storage, and, Disposal Facilities 6-5

TABLE OF CONTENTS (continued)

Page

6.2 REFERENCES 6-6

APPENDIX A: SAMPLE CALCULATIONS FOR CONTROL COSTS AND COST EFFECTIVENESS A-1

A-1: SAMPLE CALCULATIONS FOR FUGITIVE COSTS A-1

A-2: SAMPLE COST CALCULATIONS FOR INSTALLING INTERNAL FLOATING ROOFS IN FIXED ROOF TANKS A-3

A-3: SAMPLE COST CALCULATIONS FOR CONDENSER SYSTEMS (Storage Tanks and Process Vents) A-7

A-4: SAMPLE CALCULATIONS FOR SHIPPING COSTS A-11

A-5: SAMPLE COST CALCULATIONS FOR CONTROL OF PROCESS EMISSIONS A-14

REFERENCES A-24

APPENDIX B: EXISTING STATE REGULATIONS B-1

REFERENCES B-2

LIST OF TABLES

Table	Page

1-1 Ethylene Dichloride Emissions and Potential Emission Reductions 1-5

1-2 Volatile Organic Compound Emissions and Potential Emission Reductions 1-6

1-3 Estimated Ethylene Dichloride Emission Reductions From Chemical Plants as a Function of Cost Effectiveness 1-7

1-4 Estimated Volatile Organic Compound Emission Reductions From Chemical Plants as a Function of Cost Effectiveness . . 1-8

1-5 Ethylene Dichloride Emission Reduction From Lead Scavenger Blending Facilities as a Function of Cost Effectiveness . . 1-9

1-6 Volatile Organic Compound Emission Reduction From Lead Scavenger Blending Facilities as a Function of Cost Effectiveness 1-10

2-1 Physical Properties of Ethylene Dichloride 2-23

2-2 Chemical Plants Producing and/or Using Ethylene Dichloride . 2-24

2-3 Sources of Ethylene Dichloride Consumption in 1983 2-26

2-4 Costs for Retrofitting an Incineration System for the Reduction of EDC and VOC Process Emissions 2-27

2-5 VOC Emission Factors From Equipment Leaks 2-31

2-6 Costs for Implementation of Controls for EDC Fugitive Emission Sources 2-32

2-7 Costs for Implementation of Controls for VOC Fugitive Emission Sources 2-34

2-8 Control Techniques and Cost for VOC/EDC Fugitive Emission Sources 2-36

2-9 EDC and VOC Emission Reduction From Fugitive Emission Sources as a Function of Cost Effectiveness 2-37

2-10 Secondary EDC Emission Sources 2-38

2-11 Nationwide EDC Storage Patterns 2-43

LIST OF TABLES (continued)

Table Page

2-12 Controls Used on Existing Fixed Roof Tanks 2-44

2-13 Retrofit Costs for Welded Steel Internal Floatng Roofs . . . 2-45

2-14 EDC Emissions and Cost Data for Retrofitting Fixed Roof Storage Tanks with Internal Floating Roofs (Primary Seals) . 2-46

2-15 EDC Emission Reduction From Fixed Roof Tanks as a Function of Cost Effectiveness 2-50

2-16 Fixed Roof Tank Summary 2-51

2-17 VOC Emissions and Cost Data for Retrofitting Fixed Roof Storage Tanks With Internal Floating Roofs (Primary Seals) . 2-52

2-18 EDC Emissions and Cost Data for Retrofitting Fixed Roof Storage Tanks With Internal Floating Roofs (Primary and Secondary Seals) 2-56

2-19 VOC Emissions and Cost Data for Retrofitting Fixed Roof Storage Tanks with Internal Floating Roofs (Primary and Secondary Seals) 2-60

2-20 EDC Emissions From Pressure Vessels 2-64

2-21 Pressure Vessel Summary Table 2-65

2-22 Costing Data for Control of Shipping Emissions 2-66

3-1 Estimated EDC Emissions From Publicly Owned Treatment Works. 3-4

4-1 Summary of Estimated EDC Use and Emissions in the Pharmaceutical Manufacturing Industry 4-3

5-1 Producers of Lead Scavenger Additive 5-4

5-2 Emission and Control Cost Data for Process Emissions 5-5

5-3 EDC Emissions and Cost Data for Retrofitting Fixed Roof Storage Tanks With Internal Floating Roofs (Primary Seals) . 5-6

5-4 VOC Emissions and Cost Data for Retrofitting Fixed Roof Storage Tanks With Internal Floating Roofs (Primary Seals) . 5-7

LIST OF TABLES (continued)

Table Page

5-5 EDC Emissions and Cost Data for Retrofitting Fixed Roof Storage Tanks With Internal Floating Roofs (Primary and Secondary Seals) 5-8

5-6 VOC Emissions and Cost Data for Retrofitting Fixed Roof Storage Tanks With Internal Floating Roofs (Primary and Secondary Seals) 5-9

5-7 Costs for Implementation of Control Techniques for EDC Fugitive Emission Sources 5-10

5-8 Costs for Implementation of Control Techniques for VOC Fugitive Emission Sources 5-11

5-9 Secondary EDC Emission Sources 5-12

5-10 EDC Emission Summary 5-13

A-1 Control Techniques and Cost for VOC/EDC Fugitive Emission Sources A-17

A-2 Fugitive Emissions Control Cost Calculations A-18

A-3 Total Installed Capital Cost for Incinerators as a Function of Offgas Flowrate A-20

A-4 Annualized Cost Factors for Incinerators A-21

A-5 Operating Factors for Incinerators A-22

A-6 Annualized Cost Equations for Incinerators A-23

LIST OF FIGURES

Figure

Page

2-1 Internal Floating Roof Tanks 2-13

A-3.1 Installed Capital Cost vs Flow Rate for Complete Condenser System With a VOC Removal Efficiency of 95 Percent A-9

A-3.2 Annual Cost vs Flow Rate for Complete Condenser System With VOC Removal Efficiency of 95 Percent A-10

1. INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

This document describes the various sources of emissions of ethylene dichloride (EDC) and provides information on the location, emission rate, and control technologies which are being used for specific sources. Also provided in this document is information relating to opportunities to reduce EDC emissions and the cost of reducing emissions below current levels. This information will be used by the EPA along with other information, such as health effects data, to decide whether specific sources of EDC should be regulated under the Clean Air Act.

1.2 SUMMARY

1.2.1 Industry Description

Ethylene dichloride ranks No. 16 in nationwide chemical production; approximately 9.5×10^6 Megagrams (Mg) (10.5×10^6 tons) were produced in 1982. It is used primarily as a feedstock in the manufacture of other products. In 1983, 84.7 percent of domestic EDC consumption was used for the manufacture of vinyl chloride monomer (VCM), 6.1 percent for ethyl chloride, 3.4 percent for methyl chloroform amines, 2.0 percent for ethyleneamines, 1.9 percent for perchloroethylene (PCE), 1.5 percent for trichloroethylene (TCE), 0.3 percent for lead scavenger additives to leaded gasoline, and 0.1 percent for miscellaneous uses such as the processing of pharmaceuticals, grain fumigants, and pesticides.

For the purposes of this report, the following categories of EDC emissions have been defined: chemical plants, publicly owned treatment works (POTW's), pharmaceutical manufacturing plants, lead scavenger additive blending facilities and gasoline marketing facilities (bulk terminals, bulk plants, and service stations), and miscellaneous EDC-consuming industries.

1.2.2 Emission and Cost-Effectiveness Data

Emission estimates were gathered from several sources. Estimates for chemical plants and lead scavenger additive blending facilities came from industry responses to information requests. The POTW estimates are based on emission models developed in another EPA study. Pharmaceutical plant emissions were approximated using data provided by the Pharmaceutical Manufacturers Association. Finally, the estimates in the miscellaneous category were extracted from various literature sources.

The total estimated EDC emissions from each of the source categories are presented in Table 1-1. The emission rates are presented for several emission sources within each category. These emission sources are fugitive (e.g., equipment leaks), storage tanks, secondary (e.g., evaporative emissions from wastewater treatment), process vents, and shipping (e.g., loading of tank trucks, rail cars, or barges). For some categories, the emission source could not be defined within the scope of this study. These emission sources are categorized as "unassigned" in Table 1-1. Approximately 0.2 percent of the total EDC produced is emitted to the atmosphere. Ethylene dichloride is a volatile organic compound (VOC), and Table 1-2 presents total estimated VOC emissions (including EDC) from each category. Tables 1-1 and 1-2 also present the emission reductions possible (in parentheses) for EDC and VOC, respectively.

Emissions of EDC from all chemical plants with current controls total approximately 4,100 Mg/yr (4,500 tons/yr). Significant emission reductions can be realized at the chemical plants through the application of efficient control techniques on most of the sources. Fugitive emissions can be decreased through a combination of leak detection and repair programs involving periodic inspections and the application of equipment control devices. Storage tank emissions can be mitigated through the installation of internal floating roofs on fixed roof tanks. Secondary emissions can be reduced through the use of recovery equipment on the waste streams. Process emissions provide the least opportunity for further control because nearly all are currently well controlled, mainly due to the effects of the national emission standards for vinyl chloride.

Shipping emissions can be reduced by the application of recovery systems such as refrigerated condensers. Table 1-3 presents the EDC emission reductions possible from chemical plants as a function of the cost effectiveness of control. Table 1-4 presents the same information for VOC emission reductions.

In recent work sponsored by the EPA, some POTW's were identified as sources of EDC emissions. This identification was made by examining mass-balance data from 50 POTW's. The mass-balance data were used along with information on the type of treatment used at POTW's and the standard Industrial Classification Codes of the dischargers to extrapolate EDC emissions from the estimated 355 POTW's nationwide that emit EDC. These 355 POTW's were estimated to emit approximately 7,300 Mg/yr (8,050 tons/yr) of EDC. However, recent testing in Philadelphia, Pennsylvania, indicates that for the Philadelphia POTW, the emission estimate may overstate EDC emissions by a factor of 8 to 10. Further testing is planned in Baltimore, Maryland, to determine if the emission estimates can be lowered universally. Effluent limitations guidelines for the organic chemical, plastic, and synthetic fiber industries are to be promulgated in approximately 6 months. Compliance with these guidelines will reduce the amount of EDC in the wastewater streams discharged to POTW's, and therefore, EDC emissions from POTW's will also be reduced. The net reduction in EDC emissions may be offset by an increase in air emissions at some dischargers subject to the guidelines.

Pharmaceutical manufacturing plants may emit as much as 800 Mg/yr (880 tons/yr) of EDC to the atmosphere and another 500 Mg/yr (550 tons/yr) may be discharged to POTW's. A separate study of the pharmaceutical industry would be needed to determine the specific opportunities for EDC emission reductions.

Approximately 75 Mg/yr (85 tons/yr) of EDC are emitted by facilities that manufacture lead scavenger additive for use in leaded gasoline. The emission sources and control technologies for this category are similar to those for the chemical plant category. Tables 1-5 and 1-6 present EDC and VOC emission reductions, respectively, possible from lead scavenger blending facilities as a function of the cost effectiveness of control. Approximately 245 Mg/yr (270 tons/yr) of EDC are emitted from leaded gasoline marketing sources (i.e., bulk terminals, bulk plants, and service stations). It should be noted that EDC emissions from these leaded-gasoline-related sources will decline because of the phase-down of leaded gasoline.

An EPA study (made available as this document was being prepared) indicates that approximately 5,300 Mg/yr (5,900 tons/yr) of EDC may be emitted from the miscellaneous industry category. Industries in this category include the manufacture of paints, coatings, and adhesives; extraction and cleaning solvents; grain fumigants; color film; pesticides and herbicides; and copper ore leaching solvents. Emission estimates range from 100 percent of the EDC used in grain fumigants to 0 percent of that used to leach copper ore. Further study of the miscellaneous industries would be required to determine the specific opportunities for emission reductions.

1.2.3 Regulatory Requirements

The 23 chemical and lead scavenger additive plants that produce/use EDC are located in six States: Louisiana, Texas, Kentucky, California, Kansas, and New Jersey. Of these, Louisiana and Texas contain 19 of the 23 plants. All have general VOC emission regulations that are applicable to the regulation of EDC emissions. New Jersey also regulates emissions of EDC as part of its air toxics program. Ethylene dichloride emissions are also reduced as a result of the national emission standard at the 11 chemical plants that produce both VCM and EDC. Specific aspects of each State's regulations for these sources are discussed in Appendix B.

Other sources of EDC emissions (i.e., POTW's pharmaceutical manufacturing plants, gasoline marketing facilities, and miscellaneous consumers) are located throughout the United States. State regulations for reducing EDC emissions from these categories were not investigated in preparation of this report.

TABLE 1-1. ETHYLENE DICHLORIDE EMISSIONS AND POTENTIAL EMISSION REDUCTIONS

Category/source	Current emissions (emission reduction potential), Mg/yr[a] Fugitive	Storage tanks	Secondary[b]	Process vents[c]	Shipping[d]	Un-assigned[e]	Total
Chemical plants	1,900 (1,350)	730 (575)	650 (165)	420 (5)	230 (185)	-- --	3,930 (2,280)
POTW's	-- --	-- --	7,300[f] --[g]	-- --	-- --	-- --	7,300 --
Pharmaceutical	-- --	-- --	500 --[g]	-- --	0 (0)	800 [g]	1,300 --
Lead scavenger additive blending and gasoline marketing	11 (9)	21 (20)	2 (0)	41 (41)	0 (0)	245 --	320 (70)[h]
Miscellaneous	-- --	-- --	-- --	-- --	-- --	5,300 [g]	5,300 --
TOTAL							~18,150 (~2,350)

[a] Numbers in parentheses represent emission reduction potential regardless of cost.
[b] Treatment of EDC-laden wastewater.
[c] Process sources include vents from reactors, distillation columns, process tanks, etc.
[d] Tank truck, rail car, and barge loading.
[e] Specific source of emissions not known.
[f] Emission estimate based on mass-balance model.
[g] Further analysis of these sources would no doubt reveal some emission reduction potential. However, the potential could not be calculated with the information available for this report.
[h] Total reduction of EDC emissions may result from phase-out of leaded gasoline.

TABLE 1-2. VOLATILE ORGANIC COMPOUND EMISSIONS AND POTENTIAL EMISSION REDUCTIONS

Category/source	Current emissions (emission reduction potential), Mg/yr[a]						
	Fugitive	Storage tanks	Secondary[b]	Process vents[c]	Shipping[d]	Un-assigned[e]	Total
Chemical plants	3,290 (2,390)	840 (715)	170[f] (165)	2,270 (1,290)	190[f] (185)	--	6,760 (4,745)
POTW's	--	--	--	--	--	--	--
Pharmaceutical	--	--	--	--	--	--	--
Lead scavenger additive blending	48 (43)	80 (74)	--	63 (60)	--	--	190 (180)
Miscellaneous	--	--	--	--	--	--	--
TOTAL							~6,950 (~4,925)

[a] Numbers in parentheses represent emission reduction potential regardless of cost.
[b] Treatment of EDC-laden wastewater.
[c] Sources include vents from reactors, distillation columns, process tanks, etc.
[d] Tank truck, rail car, and barge loading.
[e] Specific source of emissions not known.
[f] No non-EDC VOC data reported.

TABLE 1-3. ESTIMATED ETHYLENE DICHLORIDE EMISSION REDUCTIONS FROM CHEMICAL PLANTS AS A FUNCTION OF COST EFFECTIVENESS

Cost effectiveness range, $/Mg	Nationwide emission reduction, Mg EDC/yr				
	Fugitive	Storage tanks	Secondary	Process vents	Loading
Credit	--	345	--	--	--
0-500	305	70	--	--	185
500-1,000	930	95	--	--	--
1,000-2,000	115	25	--	--	--
>2,000	--	40	165	5	--
TOTAL	1,350	575	165	5	185

TABLE 1-4. ESTIMATED VOLATILE ORGANIC COMPOUND EMISSION REDUCTIONS FROM CHEMICAL PLANTS AS A FUNCTION OF COST EFFECTIVENESS

Cost effectiveness range, $/Mg	Nationwide emission reduction, Mg VOC/yr				
	Fugitive	Storage tanks	Secondary[a]	Process vents	Loading[a]
Credit	--	480	--	--	--
0-500	2,280	75	--	--	185
500-1,000	110	90	--	--	--
1,000-2,000	--	30	--	1,285	--
>2,000	--	40	165	5	--
TOTAL	2,390	715	165	1,290	185

[a] No non-EDC VOC data reported by plants.

TABLE 1-5. ESTIMATED ETHYLENE DICHLORIDE EMISSION REDUCTION FROM LEAD SCAVENGER BLENDING FACILITIES AS A FUNCTION OF COST EFFECTIVENESS

Cost effectiveness range, $/Mg	Nationwide emission reduction, Mg EDC/yr				
	Fugitive	Storage tanks	Secondary	Process vents	Loading[a]
Credit	--	--	--	--	--
0-500	--	--	--	--	--
500-1,000	8	--	--	--	--
1,000-2,000	--	--	--	--	--
>2,000	1	20	--	41	--
TOTAL	9	20	--	41	0

[a] No loading reported by plants.

TABLE 1-6. ESTIMATED VOLATILE ORGANIC COMPOUND EMISSION REDUCTION FROM LEAD SCAVENGER BLENDING FACILITIES AS A FUNCTION OF COST EFFECTIVENESS

Cost effectiveness range, $/Mg	Nationwide emission reduction, Mg VOC/yr				
	Fugitive	Storage tanks	Secondary[a]	Process vents[a]	Loading[b]
Credit	37	--	--	--	--
0-500	6	--	--	--	--
500-1,000	--	--	--	--	--
1,000-2,000	--	21	--	--	--
>2,000	--	53	--	60	--
TOTAL	43	74	--	60	--

[a] No VOC data reported by plants.

[b] No loading reported by plants.

2. CHEMICAL PLANTS

2.1 ETHYLENE DICHLORIDE PRODUCTION AND USE

Ethylene dichloride (1,2-dichloroethane) is a clear, colorless, oily liquid with a chloroform-like, sweet odor and taste.[1] Ethylene dichloride is used as a raw material in the production of vinyl chloride monomer (VCM), various ethyleneamines, methyl chloroform (1,1,1-trichloroethane), ethyl chloride, trichloroethylene (TCE), and perchloroethylene (PCE). Its physical properties are presented in Table 2-1. The major domestic producers and users of EDC are listed in Table 2-2. The consumption of EDC is summarized in Table 2-3. Production of EDC and its use in other chemical production processes are discussed in Section 2.1.1 through 2.1.6. Emissions of EDC at chemical plants come from five primary sources: process vents; equipment leaks; secondary sources; storage tanks; and truck, rail car or barge loading. These emission sources and applicable control technologies are discussed in Sections 2.2.1 through 2.2.5, respectively.

2.1.1 Ethylene Dichloride Production

Ethylene dichloride is produced in the United States by direct chlorination of ethylene, oxychlorination of ethylene, or a combination of these methods. Also, one corporation reported production of about 2 million pounds per year of EDC as a byproduct of the manufacture of a fire retardant for urethane foam.

Direct chlorination of ethylene is accomplished in either the liquid or vapor phase according to the catalytic reaction:[2]

$$\underset{\text{ethylene}}{CH_2{=}CH_2} \quad + \quad \underset{\text{chlorine}}{Cl_2} \quad \rightarrow \quad \underset{\text{EDC}}{ClCH_2CH_2Cl}$$

Actual yields are as high as 96 to 98 percent of theoretical yields.[2] Catalysts mentioned most often in the patent literature include ferric, aluminum, cupric, and antimony chlorides.[3] The majority of industries use ferric chloride catalysts and liquid-phase reaction conditions.[2] One vapor-phase procedure reacts ethylene and chlorine at 40° to 50°C (105° to 120°F) in the presence of an ethylene dibromide (EDB) catalyst.[3,4]

The oxychlorination of ethylene proceeds via the catalytic reaction:[5]

$$2\ CH_2{=}CH_2 + O_2 \quad + \quad 4\ HCl \quad \rightarrow \quad 2\ ClCH_2CH_2 + 2\ H_2O$$

ethylene oxygen hydrogen chloride EDC water

Actual yields are usually about 90 percent of theoretical yields.[6] This reaction is normally carried out in the vapor phase in either a fixed-bed or fluid-bed reactor.[2] Cupric chloride is the most common catalyst for this reaction. Typically, the reaction pressure and temperature are maintained at 138 to 483 kilopascals (kPa) (20 to 70 pounds per square inch, gauge [psig]) and 200° to 315°C (390° to 600°F), respectively. The oxygen for this reaction may be provided in the pure form or obtained by adding air to the reaction vessel.[3]

When the EDC produced is used on site to manufacture VCM, the oxychlorination and direct chlorination processes are often used in combination in what is known as the balanced process. Most facilities use the balanced process. Vinyl chloride monomer is produced by the dehydrochlorination of EDC which also produces HCl as a byproduct. The HCl can be used in the oxychlorination of ethylene to produce more EDC.[3]

2.1.2 Vinyl Chloride Monomer Production

Approximately 96 percent of the VCM produced domestically in 1979 was made from EDC.[7]. The VCM product is purified by distillation and is usually sold for the production of polyvinyl chloride (PVC).[8]

In the production of VCM, EDC vapor is cracked in a pyrolysis furnace via the dehydrochlorination reaction as follows:

$$ClCH_2CH_2Cl \quad \overset{\rightarrow}{\Delta} \quad CH_2{=}CHCl \quad + \quad HCl$$

EDC VCM hydrogen chloride

About 50 percent conversion of EDC to VCM is achieved in the reaction. Temperatures and pressures of 450° to 620°C (840° to 1150°F) and 450 to 930 kPa (65 to 135 psig) are usually used. The process gas stream from the furnace is separated into EDC, VCM, and HCl by condensation. The unreacted liquid EDC is recycled back to the furnace, and the HCl is usually used on site in the production of EDC by the oxychlorination process.

2.1.3 Ethyl Chloride Production

Ethyl chloride is used as a refrigerant, solvent, and alkylating agent and as a starting point in the manufacture of tetraethyl lead.[9]

About 90 to 95 percent of the ethyl chloride produced in the United States comes from the hydrochlorination of ethylene. In this process, equimolar amounts of ethylene and anhydrous hydrogen chloride are mixed and introduced into a reactor containing EDC or a mixture of EDC and ethyl chloride.[10] The exothermic hydrochlorination of ethylene takes place in the presence of a catalyst such as aluminum chloride.[10,11] The vaporized products are fed into a column or flash drum to remove heavier products, and the crude ethyl chloride is purified by fractional distillation.[10]

Ethyl chloride is also produced by the thermal chlorination of ethane or by a combination of ethane chlorination and ethylene hydrochlorination. Ethylene dichloride is a byproduct of both processes.[10]

2.1.4 Methyl Chloroform Production

Methyl chloroform (1,1,1-trichloroethane) is used predominantly as a metal-cleaning solvent and is produced domestically by three processes.[12] In 1975, about 60 percent was produced by the hydrochlorination of VCM, and about 30 percent was produced by the hydrochlorination of vinylidene chloride. The remaining 10 percent was produced by the chlorination of ethane.[12] Ethylene dichloride is involved only in the first technique of methyl chloroform production. Although EDC is not used directly as a feedstock for methyl chloroform production, emissions of EDC may occur if it is an impurity in VCM or from inadvertent EDC production in the hydrochlorination and chlorination reactors.[12]

Methyl chloroform is produced from VCM by the catalytic hydrochlorination of VCM to 1,1-dichloroethane followed by thermal chlorination to methyl chloroform.[12]

$$CH_2{=}CHCl + HCl \xrightarrow{FeCl_3} CH_3CHCl_2$$

VCM   hydrogen chloride   1,1-dichloroethane

$$CH_3CHCl_2 + Cl_2 \rightarrow CH_3CCl_3 + HCl$$

1,1-dichloroethane   chlorine   methyl chloroform   hydrogen chloride

The HCl generated in the thermal chlorination step is generally recycled to react with VCM in the catalytic hydrochlorination step.[13] The catalytic hydrochlorination reaction is exothermic and usually takes place at 35° to 40°C (95° to 105°F) in the presence of ferric chloride or ferric copper catalyst.[12,13] The thermal chlorination reaction is also exothermic but noncatalytic and occurs at about 400°C (750°F).[12] The overall yields from VCM are reported to be over 95 percent.[13]

2.1.5 Ethyleneamines Production

Ethyleneamines are used in the production of carbamate fungicides, chelating agents, dimethylethylene urea resins, and diaminoethylethanol.[14]

In 1979, all ethyleneamines were produced by reacting EDC and ammonia.[6] More recently, some ethyleneamines have also been produced from ammonia and ethylene oxide.[15] The major product of both reactions is ethylenediamine; however, the ethylene oxide process is reportedly more selective for ethylenediamine with only small quantities of byproducts such as diethylenetriamine, triethylenetetramine, tetraethylenepentamine, pentaethylenehexamine, and higher polymers.[14,15]

The reaction between EDC and ammonia can be performed in either the liquid or vapor phase. In the vapor phase reaction, EDC and an excess of anyhydrous ammonia are reacted at 150°C (300°F) and 9.0 MPa (1,305 psi) in a pressure reactor. The product of this reaction is anhydrous ethlenediamine hydrochloride, which is treated with sodium hydroxide at 100°C (212°F) to yield free ethylenediamine. The product amine, or mixture of amines, is separated and purified by fractional distillation, and the excess ammonia is recovered and recycled. The mixture of product ethyleneamines is controlled by the reaction conditions and the mix of reactants.[14] With a 15:1 ratio of ammonia to EDC, the yield of ethylenediamine is about 50 percent.[15]

2.1.6 Perchloroethylene and Trichloroethylene Production

Perchloroethylene is used primarily as a dry-cleaning, textile-processing, and metal-cleaning solvent.[16] Trichloroethylene is used primarily as a metal-cleaning solvent.[16] Perchloroethylene and trichloroethylene can be produced separately or as co-products. Initially, both PCE and TCE were produced from acetylene. As EDC production capacity increased to produce VCM, and as ethylene became more available and less expensive, it became economical to also use EDC to manufacture PCE and TCE. The last acetylene-based PCE and TCE plant was closed in 1977.[16,17]

Both PCE and TCE are now manufactured by the chlorination or oxychlorination of EDC or other chlorinated ethanes.[16,17,18] In 1979, 49 percent of PCE and 91 percent of the TCE produced in the United States were made from EDC.[5] The chlorination process proceeds via the noncatalytic reactions:[6]

$$\underset{\text{EDC}}{\mathrm{ClCH_2CH_2Cl}} + \underset{\text{chlorine}}{3\,\mathrm{Cl_2}} \xrightarrow{\Delta} \underset{\text{PCE}}{\mathrm{Cl_2{=}CCl_2}} + \underset{\text{hydrogen chloride}}{4\,\mathrm{HCl}}$$

$$\underset{\text{EDC}}{\mathrm{ClCH_2CH_2Cl}} + \underset{\text{chlorine}}{2\,\mathrm{Cl_2}} \xrightarrow{\Delta} \underset{\text{TCE}}{\mathrm{CHCl{=}CCl_2}} + \underset{\text{hydrogen chloride}}{3\,\mathrm{HCl}}$$

The reaction is usually carried out at about 400° to 455°C (750° to 850°F) and at a pressure of slightly above one atmosphere. The HCl byproduct can be utilized by other processes. The PCE or TCE product is scrubbed with sodium hydroxide and purified.[16]

The oxychlorination of EDC to PCE or TCE proceeds via the catalytic reactions:[5]

$$\underset{\text{EDC}}{\mathrm{ClCH_2CH_2Cl}} + \underset{\text{chlorine}}{\mathrm{Cl_2}} + \underset{\text{oxygen}}{\mathrm{O_2}} \rightarrow \underset{\text{PCE}}{\mathrm{Cl_2C{=}CCl_2}} + \underset{\text{water}}{2\,\mathrm{H_2O}}$$

$$\begin{array}{ccccc} \mathrm{ClCH_2CH_2Cl} + & 1/2\ \mathrm{Cl_2} & + 3/4\ \mathrm{O_2} & \rightarrow \mathrm{CHCl{=}CCl_2} & + 3/2\ \mathrm{H_2\ O} \\ \text{EDC} & \text{chlorine} & \text{oxygen} & \text{TCE} & \text{water} \end{array}$$

Copper chloride is used as a catalyst. The reaction is usually carried out at about 425°C (795°F) and at a pressure of slightly above one atmosphere.[16] Hydrogen chloride can also be used as a reactant in the oxychlorination process. When HCl is used, additional O_2 is also required.[6] The amount of PCE and TCE produced by both the chlorination process and the oxychlorination process is controlled by the reactant concentrations.[16,17,18]

2.2 PROCESS VENTS

Ethylene dichloride can be emitted from process vents during its production and when it is used as a feedstock for manufacturing other chemicals. In both the direct chlorination and oxychlorination of ethylene to produce EDC, process emissions can originate from the purging of inert gases from reactor vessels and from drying, heads, and finishing columns. In the dehydration of EDC to produce VCM, unreacted EDC can be present in distillation column streams. Process emissions of EDC from the production of ethyl chloride can come from reactor vessels and distillation columns. Emissions of EDC in methyl chloroform production result from the presence of EDC as an impurity in the VCM feedstock or the production of EDC in the hydrochlorination and chlorination reactions. The hydrochlorination vents and steam stripper gas effluent vents (used to purify methyl chloroform) are the major process sources of EDC emissions. Vents from reactor vessels and dehydration and distillation columns are potential sources of EDC emissions in ethyleneamines production. During production of PCE and TCE, process emissions of EDC can result from the purging of inert gases in the neutralization and drying processes and from distillation columns. Table 2-4 identifies process vents in EDC service on a plant-specific basis.

2.2.1 Current Controls and Emissions

Thermal oxidation in incinerators or boilers is the control used on all but one process vent in EDC service at chemical plants. Emissions from several vents are typically ducted to a common incinerator or boiler. The destruction efficiency in these devices is typically

98 percent or greater, with some companies reporting values as high as 99.99 percent when the incinerator or boiler is also used to destroy hazardous wastes, as defined by the Resource Conservation and Recovery Act. (In this study, a 98 percent removal efficiency was assumed unless the company claimed test data to substantiate a higher efficiency.) The one process vent not controlled by thermal oxidation is controlled by an absorber with a reported EDC removal efficiency of 90 percent.

Current EDC and VOC emissions from process vents at chemical plants total approximately 420 and 2,250 megagrams/year (Mg/yr) (460 and 2,470 tons/yr), respectively. Emission rates of EDC and VOC from each process vent in EDC service are given in Table 2-4.

2.2.2 Additional Controls

Where the existing control efficiency for process vents was found to be less than 98 percent, the emission reductions and costs of installing a 98 percent efficiency incinerator were calculated. The cost estimate for the incinerator includes a refractory-lined carbon steel mixing and combustion chamber, 46 meter (m) (150 feet [ft]) of ductwork, fans for offgas and combustion air, a waste heat boiler for heat recovery, a flue gas caustic scrubber to remove and neutralize hydrogen chloride, and a 24-m (80-ft) high stack. The incinerator combustion temperature is 1100°C (2000°F), and its residence time is 1 second. These incinerator design parameters were based on those determined by the EPA to be appropriate for streams containing halogenated compounds, such as EDC.[19]

The capital and annualized costs of applying an incinerator to the one process vent not currently controlled with 98 percent efficiency was calculated to be approximately $4,500,000 and $1,500,000, respectively (see Table 2-4). Emissions of EDC and VOC would be reduced from 4 and 1,315 Mg/yr (4.4 and 1,445 tons/yr) to 0.1 and 26 Mg/yr (0.1 and 29 tons/yr), respectively from this vent. The resulting cost-effectiveness values of EDC and VOC control of this source are approximately $3,800,000/Mg ($3,400,000/ton) and $1,170/Mg ($1,060/ton), respectively. The noticeable difference in cost effectiveness of EDC and VOC control is because the company reports a 90 percent EDC removal efficiency of their existing control system and a 0 percent control for non-EDC VOC. Calculations showing derivation of capital and annualized costs are given in Appendix A.

2.3 FUGITIVE SOURCES

Process components in EDC service that are potential sources of fugitive emissions are pump seals, compressors, flanges, valves, pressure relief devices, sample connections, and open-ended lines (lines closed during normal operation that would be used during maintenance operations). Emission factors used in estimating fugitive VOC emissions from these equipment types are shown in Table 2-5.

2.3.1 Current Controls and Emissions

Currently, the majority of the facilities examined in this document utilize some type of control technique on all or part of their fugitive sources. Those using in-plant monitoring systems were analyzed by EPA and assigned an efficiency ranging from 0 to 100 percent based on a judgment of the effectiveness of the system against one of known effectiveness. The control techniques judged to be effective (>0 percent efficient) currently in use by industry are as follows:

1. Pressure relief devices vented to either a flare or an incinerator (98 percent efficiency);
2. Closed loop sampling systems (100 percent efficiency);
3. Blind flange or secondary valve on all open ended lines (100 percent efficiency);
4. Pressure relief devices equipped with rupture disks (100 percent efficiency); and
5. Leak detection and repair program using ethylene dichloride fixed point monitors for detecting pump, valve, flange and compressor seal leaks (33 percent efficiency).

Current fugitive emissions of EDC from chemical plants producing or using EDC total 1,930 Mg/yr (2,120 tons/yr), and range from 2 to 360 Mg/yr (2 to 395 tons/yr) per plant. Fugitive emissions of VOC at these plants total 3,370 Mg/yr (3,710 tons/yr) and range from 5 to 580 Mg/yr (6 to 640 tons/yr) of VOC per plant. (See Tables 2-6 and 2-7 for plant-specific information.)

For most plants, fugitive emissions were calculated by multiplying the component fugitive emission factors (see Table 2-5) by the corresponding number of components in a plant and summing the emissions for each component type. For four plants, data were insufficient to follow this procedure. Fugitive emissions were estimated at these plants by using an average of the fugitive emissions calculated for similar plants.

2.3.2 Additional Controls

This section presents the cost and removal efficiency of applying the same fugitive emission controls that were adopted for control of benzene fugitive emissions.[20] The specific control techniques, control efficiencies and capital and annualized costs per component are given in Table 2-8.

Tables 2-6 and 2-7 present the costs, EDC and VOC emission reduction potential, and cost effectiveness of controlling fugitive emissions on a plant-specific basis. By adopting the fugitive control program, EDC and VOC emissions would be reduced by 1,350 and 2,390 Mg/yr (1,490 and 2,630 tons/yr), respecively. This would lower EDC and VOC emissions from fugitive sources to 580 and 990 Mg/yr (640 and 1,090 tons/yr), respectively. Table 2-9 summarizes the emission reduction potential and cost-effectiveness data for EDC and VOC control.

The cost effectiveness (based on EDC) ranged from a low of $150/Mg ($135/ton) to a high of about $1,600/Mg ($1,450/ton). However, if VOC emissions are considered the cost effectiveness of controls is under $1,000/Mg ($910/ton) for all plants. Sample calculations of the control costs are given in Appendix A.

2.4 SECONDARY EMISSIONS

2.4.1 Emission Sources

Secondary emissions are those air emissions resulting from the treatment or disposal of wastewater, liquid waste, or solid wastes. The chemical plants surveyed identified several types of EDC-laden waste streams, including process wastewater, contaminated floor drains, water used to clean equipment, and residual heavy-ends and tars. Table 2-10 identifies the EDC-laden waste streams, treatment techniques used, and

EDC emissions on a plant-specific basis. Insufficient data were reported to estimate total VOC emissions.

Waste treatment or disposal techniques include collection in a closed system followed by steam stripping to collect and recycle the EDC, biotreatment, incineration, and deep well injection. Of these, biotreatment is responsible for most of the secondary EDC emissions to the atmosphere. This is because EDC is not readily biodegradable.[21] (Biotreatment is used to remove other pollutants.) Ethylene dichloride thus evaporates from treatment ponds, especially during aeration. Estimates provided by industry of the amount of EDC that evaporates range from approximately 0 to 96 percent; 50 percent is the most common value reported. The evaporation rate depends on such parameters as pond surface area and depth, atmospheric temperature, and aeration practices.

2.4.2 Current Controls and Emissions

Currently, there are no add-on controls present on biotreatment emission sources in the EDC production/use chemical industry. Secondary emissions of EDC total approximately 650 Mg/yr (720 tons/yr).

2.4.3 Additional Controls

The feasibility of applying covers to biotreatment ponds was investigated. Under this concept, a rigid equipment cover fabricated from such materials as aluminum or plastic would allow evaporative emissions to be collected and routed to a control device.[22] This approach, however, could hinder biodegradation by reducing the amount of oxygen entering the waste stream by surface aerators.

Secondary emissions from the treatment of liquid wastes can be reduced by lowering the EDC content of the waste stream prior to biotreatment. Process wastewater, contaminated floor drains, and flush water can be collected and passed through a steam stripper to remove EDC. Information received from the plants through the information requests was insufficient to perform a detailed evaluation of the possible emission reductions or the costs of pretreating individual secondary waste streams.

Information was obtained from a vendor of steam strippers for a 0.5 m^3/min (130 gal/min) waste stream saturated with EDC at 21°C (70°F).[23] (Waste flows reported by the industry ranged from 0.06 to 5.8 m^3/min [15 to 1,500 gal/min]). This system would have a design emission rate of

100 ppm EDC in the waste stream (98.8 percent removal), would operate continuously, and would have a rectifying section for EDC recovery. The installed capital cost of the unit would be $400,000. For a saturated stream at these flow rates, EDC recovery would be favorable, resulting in an annualized cost of approximately $235,000 and a cost effectiveness of approximately $85/Mg ($75/ton).[24] However, scaling this unit to the flows reported and using the reported EDC emission levels (0 to 200 Mg/yr [0 to 220 tons/yr]), cost-effectiveness values exceed $2,500/Mg ($2,260/ton). (These high values result from the high flow rates and less-than-saturated flow streams.) Because of the lack of detail on current plant-specific treatment systems, the emission reductions obtainable and associated costs should be treated as general indications of the impacts of these controls. Actual impacts for both emission reductions and costs may be higher or lower than the stated values.

2.5 STORAGE TANKS

2.5.1 Current EDC Storage Patterns

Four types of storage vessels are currently used to store EDC:

1. Fixed roof tanks;
2. Internal floating roof tanks;
3. Open top tanks; and
4. Pressure vessels.

2.5.1.1 Fixed Roof Tanks.[25] As shown in Table 2-11, fixed roof tanks account for about 73 percent of all vessels used to store EDC. A typical fixed roof tank consists of a cylindrical steel shell with a cone- or dome-shaped roof that is permanently affixed to the tank shell. A breather valve (pressure-vacuum valve), which is commonly installed on many fixed roof tanks, allows the tank to operate at a slight internal pressure or vacuum. Because this valve prevents the release of vapors only during very small changes in temperature, barometric presssure, or liquid level, the emissions from a fixed roof tank can be appreciable.

The major types of emissions from fixed-roof tanks are breathing and working losses. Breathing loss is the expulsion of vapor from a tank vapor space that has expanded or contracted because of daily changes in ambient temperature and barometric pressure. The emissions occur in the absence of any liquid level change in the tank.

Working losses are those that occur when the tank is filled or emptied. Filling losses are associated with an increase of the liquid level in the tank. The vapors are expelled from the tank when the pressure inside the tank exceeds the relief pressure as a result of filling. Emptying losses occur when the air that is drawn into the tank during liquid removal expands as a result of reaching temperature and saturation equilibrium, thus exceeding the fixed capacity of the vapor space and overflowing through the pressure vacuum valve.

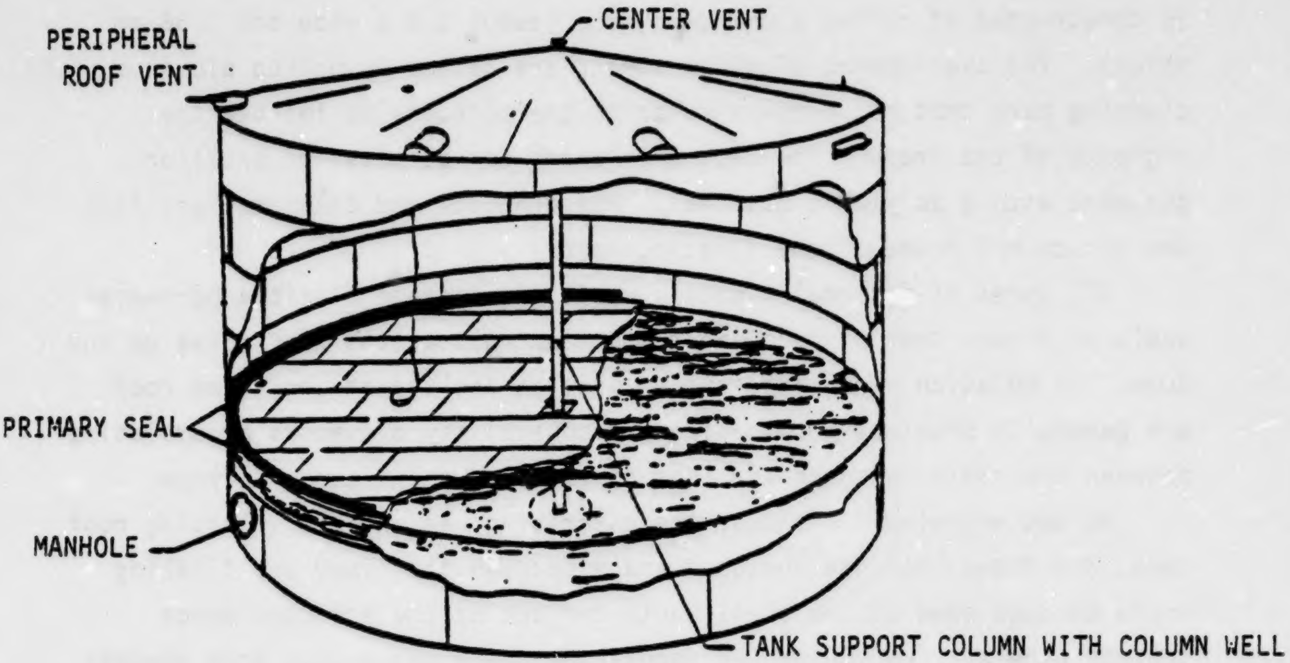
Fixed roof tanks account for about 95 percent of the 610 Mg/yr (670 tons/yr) of EDC emissions from storage vessels. Many storage vessels contain mixtures of EDC and other organic liquids. If emissions of VOC's are considered, fixed roof tanks still account for about 804 Mg/yr (886 tons/yr), or 95 percent, of emissions from storage vessels.

2.5.1.2 Internal Floating Roof Tanks.[26] As shown in Figure 2-1, an internal floating roof tank has both a permanently affixed roof and a roof that floats inside the tank on the liquid surface (contact roof) or is supported on pontoons several inches above the liquid surface (noncontact roof). The internal floating roof rises and falls with the liquid level.

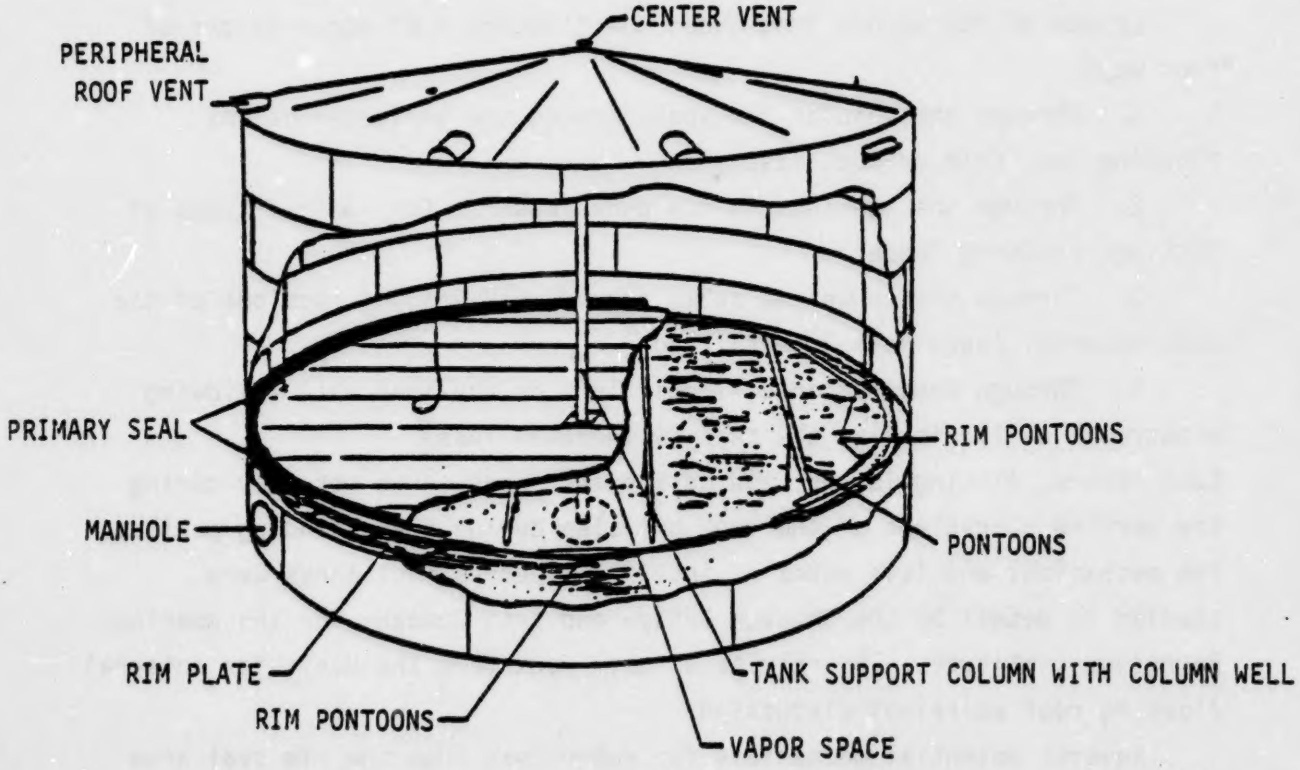
Contact-type roofs include (1) aluminum sandwich panel roofs with a honeycombed aluminum core floating in contact with the liquid; (2) resin coated, glass fiber reinforced polyester (RFP) buoyant panels, floating in contact with the liquid; and (3) pan-type steel roofs, floating in contact with the liquid with or without the aid of pontoons.

Several variations of the pan-type contact steel roof exist. The design may include bulkheads, or open compartments, around the perimeter of the roof to minimize and/or localize the effects of liquid that may leak or spill onto the deck. Alternately, the bulkheads may be covered to form sealed compartments (i.e., pontoons), or the entire pan may be covered to form a sealed, double-deck, steel floating roof. Construction is generally welded steel.

Noncontact roofs typically consist of an aluminum deck on an aluminum grid framework supported above the liquid surface by tubular aluminum pontoons. The deck skin for the noncontact-type floating roofs typically


CENTER VENT
PERIPHERAL ROOF VENT
PRIMARY SEAL
MANHOLE
TANK SUPPORT COLUMN WITH COLUMN WELL

A. CONTACT INTERNAL FLOATING ROOF.


CENTER VENT
PERIPHERAL ROOF VENT
PRIMARY SEAL
RIM PONTOONS
MANHOLE
PONTOONS
RIM PLATE
TANK SUPPORT COLUMN WITH COLUMN WELL
RIM PONTOONS
VAPOR SPACE

B. NONCONTACT INTERNAL FLOATING ROOF.

Figure 2-1. Internal floating roof tanks.[26]

is constructed of rolled aluminum sheets (about 1.5 m wide and 0.58 mm thick). The overlapping aluminum sheets are joined by bolted aluminum clamping bars that run perpendicular to the pontoons to improve the rigidity of the frame. The deck skin seams can be metal on metal or gasketed with a polymeric material. The pontoons and clamping bars form the structural frame of the floating roof.

All types of internal floating roofs incorporate flexible perimeter seals or wipers that slide against the tank wall as the roof moves up and down. Circulation vents and an open vent at the top of the fixed roof are generally provided to minimize the possibility of vapors accumulating between the roofs in concentrations approaching the flammable range.

As ambient wind flows over the exterior of an internal floating roof tank, air flows into the enclosed space between the fixed and floating roofs through some of the shell vents and out of the enclosed space through others. Any VOC or EDC vapors that have evaporated from exposed liquid surface and that have not been contained by the floating roof will be swept out of the enclosed space.

Losses of VOC vapors from under the floating roof occur in one of four ways:

1. Through the annular rim space around the perimeter of the floating roof (rim or seal losses);
2. Through the openings in the deck required for various types of fittings (fitting losses);
3. Through the nonwelded seams formed when joining sections of the deck material (deck seam losses); and
4. Through evaporation of liquid left on the tank wall following withdrawal of liquid from the tank (withdrawal loss).

Seal losses, fitting losses, and deck seam losses occur not only during the working operations of the tank but also during free standing periods. The mechanisms and loss rates of internal floating roof tanks were studied in detail by the Chicago Bridge and Iron Company for the American Petroleum Institute. The results of this work form the basis for internal floating roof emissions discussion.

Several potential mechanisms for vapor loss from the rim seal area of an internal floating roof tank can be postulated:

1. Circumferential vapor movement underneath vapor-mounted rim seals;

2. Vertical mixing, due to diffusion or air turbulence, of the vapor in gaps that may exist between any type of rim seal and the tank shell;

3. Expansion of vapor spaces in the rim area due to temperature or pressure changes;

4. Varying solubility of gases, such as air, in the rim space liquid due to temperature and pressure changes;

5. Wicking of the rim-space liquid up the tank shell; and

6. Vapor permeation through the sealing material.

Vapor permeability is the only potential rim seal area loss mechanism that is readily amenable to independent investigation. Seal fabrics are generally reported to have very low permeability to typical hydrocarbon vapors, such that this source of loss is not considered to be significant. However, if seal material is used that is highly permeable to the vapor from the stored liquid, the rim seal loss could be significantly higher than that estimated from the rim seal loss equation used to calculate EDC emissions from internal floating roof tanks. Particularly when dealing with a chemical product, such as EDC, rather than petroleum liquids, attention must be paid to the properties of the individual compound being stored. For instance, benzene is suspected of having permeability losses that equal or exceed convective and diffusion losses from the seal. Additional permeability data for liquid/seal material combinations must be developed to characterize fully the significance of permeability losses. Such data do not exist.

The extent to which any or all of these mechanisms are responsible for the total fitting loss is not known. The relative importance of the various mechanisms probably depends on the type of fitting, and the design of the fitting seal.

Internal floating roofs are typically made by joining several sections of deck material together, resulting in seams in the deck. To the extent that these seams are not completely vapor tight, they become a source of loss. Generally the same loss mechanisms discussed for deck fittings may apply to deck seams.

Withdrawal loss is another source of emissions from floating roof tanks. When liquid is withdrawn from a tank, the floating roof is lowered, and a wet portion of the tank wall is exposed. Withdrawal loss is the evaporation of liquid from the wet tank wall.

Currently, nine internal floating roof tanks are used to store EDC. Total EDC emissions from these vessels are estimated to be about 9 Mg/yr (10 tons/yr).

2.5.1.3 Open Top Tanks. EDC is also stored in three open top tanks. Open top tanks are cylindrical shells with no roof. A lighter liquid is floated on the surface of the primary liquid EDC, forming an evaporative barrier. Total EDC emissions were etimated to be less than 1 Mg from these three tanks.

2.5.1.4 Pressure Vessels. Pressure vessels are designed to withstand relatively high internal pressures. They are generally used for storing highly volatile and/or toxic materials and are constructed in various sizes and shapes, depending on the operating pressure range. Noded spheroid and hemispheroid shapes are generally used for low-pressure vessels (117 to 207 kPa); horizontal cylinder and spheroid designs are generally used for high-pressure tanks (up to 1,827 kPa). Because high pressure vessels are generally operated in a closed system at the presure of the stored material, losses are not generally incurred. However, low pressure vessels (2-15 psig) can emit EDC during filling operations.

Emissions from the 11 pressure vessels used to store EDC totaled about 16 Mg/yr (18 tons/yr). Four low pressure vessels are responsible for over 15 Mg/yr (17 tons/yr).

2.5.2 Current Controls and Emissions

In general, because of the low emission rates of internal floating roof tanks and pressure vessels, these tank types are not currently equipped with additional controls. Also, the three open top tanks are not currently controlled. Therefore, the focus of this discussion is on fixed roof tanks.

Emissions from 65 fixed roof tanks currently are ducted to an emission control device (Table 2-12). These devices include thermal oxidation units (incinerators) and various types of refrigeration systems. The efficiency of incinerators was reported to be between 98 and

99.99 percent, while the efficiency reported for refrigeration systems ranged from 37 to 99.5 percent. The average efficiency of a refrigeration system was estimated at about 90 percent.

The remaining 39 fixed roof tanks are either uncontrolled, or have low efficiency controls. Low efficiency controls include devices such as conservation vents.

2.5.3 Additional Emission Control Techniques

2.5.3.1 Fixed Roof Tanks. Emissions from uncontrolled fixed roof tanks could be reduced through the use of add-on controls (such as vent condensers) or by equipping the tank with an internal floating roof. Condensers were evaluated, but were more costly than internal floating roofs. Ducting emissions to existing process incinerators was not examined because there were no data on existing incinerator capacities or the proximity of the tanks to the incinerator. Therefore, only internal floating roofs were considered.

Depending on the type of roof and seal system selected and on tank parameters, an internal floating roof will reduce the fixed roof tank emissions by about 93 to 99 percent. An internal floating roof, regardless of design, reduces the area of exposed liquid surface in the tank. Reducing the area of exposed liquid surface, in turn, decreases the evaporative losses. The relative effectiveness of one internal floating roof design over another is a function of how well the floating roof can be sealed.

Two types of internal floating roofs were examined in this study. These were:

1. A welded steel, contact, internal floating roof with a Teflon®, liquid-mounted, primary seal only; and

2. A welded steel, contact, internal floating roof with a Teflon®, liquid-mounted primary seal, and a Viton® secondary seal. These controls were attributed emission reductions of 94 percent and 97 percent, respectively.[27,28]

These controls are significnatly more expensive than typical, bolted, aluminum noncontact internal floating roofs. However, compability problems with EDC prevent the use of typical deck materials such as aluminum, and typical seal fabrics, such as polyurethane-coated nylon.

Table 2-13 presents a summary of the costing methodology. The details of the costing are presented in Appendix A. It should be recognized that the internal floating roof physically occupies a finite volume of space that takes away from the maximum liquid storage capacity of the tank. When completely full, the floating roof touches or nearly touches the fixed roof. Consequently, the effective height of the tank decreases, thus limiting the storage capacity. The reduction in the effective height varies from about 0.5 to 2 feet depending on the type and design of the floating roof employed. This reduction in capacity was not considered as a cost.

The emission reduction and costs of retrofitting 40 fixed roof tanks with internal floating roofs equipped with liquid-mounted primary seals only was evaluated. These tanks were selected because, with one exception, they are not currently controlled with incinerators or refrigeration systems. The one exception was a tank controlled with a 37 percent effective vent condenser. The results of this analysis are presented in Table 2-14.

It should be noted that no plant-specific data were available for the Borden Chemical or Diamond Shamrock plants. The values for these plants were generated by using industry averages for similar plants. However, tanks that are highly controlled have virtually no emissions, while larger uncontrolled fixed roof tanks may have very large emissions. EDC storage tanks vary between these two extremes. In this type of situation, averages are very misleading, and are presented here only for completeness. The following discussion and tables do not include these plants.

The results of the analyses are summarized in Tables 2-15 and 2-16. As shown in the tables, a small number of fixed roof tanks account for the majority of emissions. About 89 percent of the available EDC emission reduction can be obtained for less than $1,000/Mg ($910/ton), and 93 percent of the available EDC emission reduction can be obtained for less than $2,000/Mg ($1,820/ton).

As shown in the Table 2-16, 70 tanks emit less than 1 Mg/yr (1.1 tons year) per tank. These low emissions result from existing high efficiency controls (such as incinerators), small volumes, a low percentage of EDC stored, or a combination of all these factors. Because of the low EDC emissions, the cost effectiveness of additional controls (where applicable) always exceeds $4,300/Mg ($3,900/ton).

Forty-two fixed roof tanks have EDC emissions between 1 and 10 Mg/yr (1.1 and 11 tons/yr). These account for about 175 Mg/yr (193 tons/yr) of EDC emissions. Some of the tanks are already controlled. The cost effectiveness of equipping these vessels with internal floating roofs ranged from a credit to $10,000/Mg ($9,070/ton) of EDC controlled.

The cost effectiveness of controls for vessels that emit more than 10 Mg/yr (11 tons/yr) is generally a credit, but does range up to $1,500/Mg (1,350/ton) in one case. These 12 tanks are responsible for about 73 percent of the fixed roof tank emissions and about 76 percent of all EDC storage emissions.

Because some EDC storage vessels also emit other VOC's, the VOC emission reduction that would be obtained by controls was also examined. The results of this analyses are presented in Table 2-17. The only substantial changes in cost effectiveness occur in six tanks. The cost effectiveness of controls for four tanks decreases from values in excess of $10,000/Mg (9,070/ton) to net credits. This is because these vessels store liquids that have a low EDC content. The cost effectiveness of controlling the other two tanks drops from about $2,500/Mg to about $1,300/Mg ($2,300/ton to $1,200/ton). These six tanks have EDC emissions that total about 9 Mg/yr (10 tons). The major conclusion from the analysis of VOC emissions is that if tanks were to be regulated based on cost effectiveness, the additional consideration of VOC emissions would make little difference in the overall end result; both in terms of the total EDC emission reduction that would be obtained and the number of sources that would be controlled.

The impacts of adding secondary seals to the internal floating roof were calculated and the results of this analysis are presented in Tables 2-18 and 2-19 for EDC and VOC, respectively. The calculated incremental cost effectiveness of a secondary seal over a liquid-mounted primary seal always exceeds $28,000/Mg ($25,400/ton).

2.5.3.2 Pressure Vessels. As shown in Table 2-20, four pressure vessels account for the majority of emissions from this tank type. The noncylindrical shape of this tank precludes the installation of internal floating roofs as a control system. Therefore, a refrigerated vent condenser was evaluated.

The results of the analysis are contained within Tables 2-14 and 2-17, but is also presented in Table 2-21. Of particular note is the radical drop in cost effectiveness of controlling the largest single tank if VOC is considered. This tank with EDC emissions of 5.7 Mg/yr (6.3 tons), is responsible for about 35 percent of EDC emission from all pressure vessels.

2.5.3.3 Internal Floating Roof and Open Top Tanks. Additional controls were not extensively considered for existing internal floating roof tanks. It would be possible to degass the tank and gasket existing fittings. This would provide an emission reduction of about 0.1 Mg/yr per tank, or about 0.9 Mg (1 ton) nationwide. Previous studies have shown that gasketing fittings is not cost effective if the cost of degassing is included. These controls may be cost effective (≅$300/Mg) if the gaskets are installed when the tank has been cleaned and degassed for other reasons.[29]

Emissions from open top tanks could be reduced by doming the tank and adding an internal floating roof. The cost effectiveness of adding only the internal floating roof would be in excess of $9,500/Mg ($8,600/ton) in all cases.

2.6 TANK TRUCK/RAIL CAR/BARGE LOADING

2.6.1 Emission Sources

Ethylene dichloride is transported from producer to user by either tank truck, railroad tank car, or barge. One manufacturer reports shipping EDC in portable container drums. Emissions of EDC to the atmosphere primarily occur during loading of the vehicle as a result of vapors residing in empty cargo spaces being displaced by the liquid being loaded. These vapors result from evaporation of residual product from a previous load and those generated in the space as new EDC is being loaded. The total evaporative loss from loading operations is a function of the physical and chemical properties of the previous and new cargos, the method used for loading or unloading the cargos, and the service history of the cargo carrier.[30] Because other VOC components are typically present only in minute quantities as impurities in EDC, non-EDC VOC emissions would be negligible and are consequently not addressed in this report.

2.6.2 Current Controls and Emissions

Table 2-22 presents current shipping mode, control systems employed, and emission data on a plant-specific basis. Current EDC emissions reported by the industry are approximately 225 Mg/yr (250 tons/yr).

Loading emissions can be reduced by submerged loading, vapor recovery systems, incineration, and vapor balance systems. These control options are described below.

2.6.2.1 Submerged Loading. Submerged loading is the introduction of liquid EDC into the tank being filled with the transfer line outlet being below the liquid surface. Submerged loading minimizes droplet entrainment, evaporation, and turbulence. (This is compared to splash loading where the transfer line outlet is at the top of the tank and liquid free-falls into the tank.) Emission reductions can range from 0 to 65 percent.[31] Six companies report utilizing, or have the facilities to utilize, submerged loading.

2.6.2.2 Vapor Recovery Systems. Vapor recovery equipment recovers the EDC and VOC vapors displaced during loading operations by use of refrigeration (e.g., vent condensers). Control efficiencies range from 90 to 98 percent, depending on the nature of the emissions and the type of recovery equipment used.[32] In the case of barges, the vapor recovery system may be located on the barge, rather than on shore. Three companies currently use vapor recovery systems.

2.6.2.3 Incineration. Venting emissions to an incinerator can give 97 to 99 percent emissions control. Three companies utilize incineration.

2.6.2.4 Vapor Balance System. The vapor balance system consists of a pipeline between the vapor spaces of the receiving vehicle and the unloading storage tanks, which essentially creates a closed system allowing the vapor spaces of the storage tank and the vehicle to balance with each other. The net effect of the system is to transfer vapor displaced by liquid entering the vehicle to the storage tank during loading operations. If a system is leak tight, very little or no air is drawn into the system, and venting, due to compression, is also substantially reduced. However, vapor balance systems cannot be utilized with floating roof storage tanks. Three companies have the ability to utilize a vapor balance system with fixed roof tanks.

2.6.3 Additional Controls

Each of the above control options are in use by the EDC industry although some shippers do not control their loading emissions. Many of the plants report no shipping of EDC; they use it all captively. Only one plant, responsible for approximately 84 percent of reported EDC emissions from tank trucks, rail cars, and barges, provided enough information to calculate emission reduction and cost values for a barge loading operation. For this system, a refrigerated vent condenser system would reduce EDC barge loading emissions by 184 Mg/yr (203 tons/yr) at a net annualized cost of $24,900 and a cost effectiveness of $135/Mg ($123/ton) of EDC reduction. These costs are also presented in Table 2-22, and sample calculations are provided in Appendix A. The system that was evaluated employs two-stage cooling for water vapor removal. This design cools the stream down to -70°C (-95°F) and has a removal efficiency of 98 percent. The system includes a skid mounted refrigerated vent condenser, concrete pad, electric feeder, and vapor piping.

The emission reductions achievable by controlling barge loading operations depend on the volume shipped per year, information not provided by most of the companies. The cost of control for tank truck and rail car loading is highly dependent on the type of vehicle being used and its compatibility with the various control systems. Many of the companies reported being able to use control systems on appropriately equipped tank trucks, rail cars, and barges. Because of the relationship between control system and vehicle adaptability, no costs for tank truck or rail car loading operations are presented.

TABLE 2-1. PHYSICAL PROPERTIES OF ETHYLENE DICHLORIDE[a]

Molecular weight	98.96
Density, g/ml at 20°C	1.2351
Melting point, °C (°F)	-35.36 (-31.65)
Boiling point °C (°F)	83.47 (182.25)
Index of refraction, 20°C	1.4448
Vapor pressure, torr, at °C (°F)	
-44.5 (-48.1)	1
-13.6 (7.5)	10
10.0 (50.0	40
29.4 (84.9)	100
64.0 (147.2)	400
982.4 (180.3)	760
Solubility in water, ppm w/w/ at °C (°F)	
20 (68)	8,690
30 (86)	9,200
Biochemical oxygen demand (5 days, %	0
Theoretical oxygen demand, mg/mg	0.97
Measured chemical oxygen demand, mg/mg	1.025
Vapor density (air = 1)	3.35
Flash point, open cup, °C (°F)	13.0 (55.4)
Ignition temperature, °C (°F)	413.0 (775.4)
Explosive limit, % volume in air	
Lower	6.2
Upper	15.9
Specific resistivity	9.0 x10^6
Viscosity, cP, at 20°C	0.840
Dielectric constant	10.45
Surface tension, dyne/cm	33.23
Coefficient of cubical expansion, 10° to 30°C	0.0016
Latent heat of fusion, cal/g	21.12
Latent heat of vaporization, cal/g, at boiling point	77.3
Specific heat, cal/g °C	
Liquid at 20°C	0.308
Vapor, 1 atm at 97.1°C	0.255
Critical temperature, °C (°F)	288 (550)
Critical pressure, atm	53
Critical density, g/cm^3	0.44
Thermal conductivity, Btu/h-ft^2 at 20°C	0.825
Heat of combustion, cP, kcal/g-mole	296.36
Dipole moment, ESU	1.57 x 10^{-18}
Conversion factors, 25°C 760 torr	1 mg/L = 1 g/m^3 = 247 ppm 1 ppm = 4.05 gm/m^3 = 4.05 g/L

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[a] Reference 33.

TABLE 2-2. CHEMICAL PLANTS PRODUCING AND/OR USING ETHYLENE DICHLORIDE[a]

Product	Producer	Location
Ethylene dichloride	Arco Chemicals	Port Arthur, Tex.
	B. F. Goodrich	Calvert City, Ky.
		Convent, La.
		LaPorte, Tex.
	Diamond Shamrock	Deer Park, Tex.
	Dow Chemical[b]	Freeport, Tex.
		Oyster Creek, Tex.
		Plaquemine, La.
	E. I. duPont	Westlake, La.
	Ethyl Corporation	Baton Rouge, La.
	Formosa Plastics	Baton Rouge, La.
		Point Comfort, Tex.
	Georgia Pacific	Plaquemine, La.
	Olin Corporation	Lake Charles, La.
	PPG Industries	Lake Charles, La.
	Shell Chemical Co.	Deer Park, Tex.
	Vulcan Chemicals	Geismar, La.
Vinyl chloride monomer	B. F. Goodrich	LaPorte, Tex.
		Calvert City, Ky.
	Borden Chemical[c]	Geismar, La.
	Dow Chemical[d]	Plaquemine, La.
		Oyster Creek, Tex.
	E. I. duPont	Westlake, La.
	Formosa Plastics	Baton Rouge, La.
		Point Comfort, Tex.
	Georgia Pacific	Plaquemine, La.
	PPG Industries	Lake Charles, La.
	Shell Chemical Co.	Deer Park, Tex.
Ethyl Chloride	B. F. Goodrich	Convent, La.
	Dow Chemical[e]	Freeport, Tex.
Methyl chloroform	Dow Chemical[f]	Freeport, Tex.
	PPG Industries	Lake Charles, La.
Ethyleneamines	Dow Chemical[g]	Freeport, Tex.
	Union Carbide	Taft, La.
Perchloroethylene	Diamond Shamrock	Deer Park, Tex.
	Dow Chemical[h]	Freeport, Tex.
	PPG Industries	Lake Charles, La.
	Vulcan Chemical	Geismar, La.
		Wichita, Kans.

(continued)

TABLE 2-2. (continued)

Product	Producer	Location
Trichloroethylene	Dow Chemical[i] PPG Industries	Freeport, Tex. Lake Charles, La.

[a] Data from information requests unless otherwise noted.
[b] Reference 34.
[c] Reference 35.
[d] Reference 36.
[e] Reference 37.
[f] Reference 38.
[g] Reference 11.
[h] Reference 17.
[i] References 17 and 39.

TABLE 2-3. SOURCES OF ETHYLENE DICHLORIDE CONSUMPTION IN 1983[a]

	EDC consumption		
Use	(gigagrams)	(10^6 pounds)	Percent of total
Vinyl chloride monomer	6,270	13,825	84.7
Ethyl chloride	405	895	6.1
Methyl chloroform	250	550	3.4
Ethyleneamines	150	325	2.0
Perchloroethylene	140	315	1.9
Trichloroethylene	115	250	1.5
Lead scavenger	20	45	0.3
Pharmaceuticals	1	2	--
Miscellaneous	5	15	0.1
TOTAL	~7,400	~16,300	100.0

[a] Reference 40.

TABLE 2-4. COSTS FOR RETROFITTING AN INCINERATION SYSTEM FOR THE REDUCTION OF EDC AND VOC PROCESS EMISSIONS 1984 Dollars[a]

Plant/location, Process source[b]	Current control technology[b]	Current EDC/VOC control efficiency, %[b]	Current EDC/VOC emissions, Mg/yr[b]	Applicable additional controls	EDC/VOC emission reduction, Mg/yr[c]	Capital cost,[a,d,e] $	Net annual cost,[a,d,e] $	Cost effectiveness[f] EDC emissions, $/Mg	VOC emissions, $/Mg
Arco Chemicals, Port Arthur, Tex. EDC manufacture (a) Incinerator stack EDC-9[g]	Incinerator/ scrubber	98/98[h]	30/30	N/A[i]	N/A	N/A	N/A	N/A	N/A
B. F. Goodrich, Calvert City, Ky. EDC & VCM manufacture (a) Oxy absorber vent			4.0/1,314	Incinerator	3.9/1,288	4,540,000	1,500,000	3,800,000	1,170
(b) Primary incinerator			240/287	N/A	N/A	N/A	N/A	N/A	N/A
B. F. Goodrich, Convent, La. EDC manufacture (a) Waste gas boiler			0/0	N/A	N/A	N/A	N/A	N/A	N/A
B. F. Goodrich, LaPorte, Tex. EDC/VCM manufacture (a) Incinerators A & B			1.3/8.5	N/A	N/A	N/A	N/A	N/A	N/A
Borden Chemicals[j] VCM manufacture Geismar, La.	Incinerator/ scrubber	98/98	41/230	N/A	N/A	N/A	N/A	N/A	N/A
Diamond Shamrock[j] EDC/PCE manufacture Deer Park, Tex.	Incinerator/ scrubber	98/98	1.3/3.0	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical EDC plant Freeport, Tex. OC-EDC (a) Process vent	Flare	--[k]/98[h]	0/1.3	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical 1,1,2 Trichloroethane plant Freeport, Tex. (a) 1,1,2 Trichloroethane			0/0	N/A	N/A	N/A	N/A	N/A	N/A

(continued)

TABLE 2-4. (continued)

Plant/location Process source[b]	Current control technology[b]	Current EDC/VOC control efficiency, %[b]	Current EDC/VOC emissions, Mg/yr[b]	Applicable additional controls	EDC/VOC emission reduction, Mg/yr[c]	Capital cost,[a,d,e] $	Net annual cost,[a,d,e] $	Cost effectiveness[f] EDC emissions, $/Mg	Cost effectiveness[f] VOC emissions, $/Mg
Dow Chemical[m] Trichlor plant Freeport, Tex.									
(a) TCE	--	--	--	--	--	--	--	--	--
Dow Chemical, Oyster Creek, Tex. EDC/VCM manufacture									
(a) Unit A	Material recovery[i]	99.99/99.99	0.005/0.025	N/A	N/A	N/A	N/A	N/A	N/A
(b) Unit B	Scrubber	99.99/99.99	0.04/0.54	N/A	N/A	N/A	N/A	N/A	N/A
(c) Unit C	Scrubber	99.99/99.99	0.06/0.49	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical (Vinyl I) Plaquemine, La. EDC manufacture									
(a) Gaseous vent (EDC finishing)	Combustion device	99.9/99.9	0.09/0.59	N/A	N/A	N/A	N/A	N/A	N/A
(b) Gaseous vent (EDC reaction)	Combustion device	99.9/99.9	1.67/2.04	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical (Vinyl II) Plaquemine,La. EDC manufacture									
(a) Gasous vent (Oxy vent)	Material recovery[i]	99.9/99.9	7.1/31.1	N/A	N/A	N/A	N/A	N/A	N/A
(b) Gaseous vent (EDC finishing)	Material recovery[i]	99.9/99.9	1.0/1.7	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical[m] Ethyleneamines plant Texas Division	--	--	--	--	--	--	--	--	--
E. I. duPont (Conoco) Westlake, La. EDC manufacture									
(a) Direct chlorination reactor accumulator (T-101)			0.01/0.03	N/A	N/A	N/A	N/A	N/A	N/A
(b) EDC acid wash tank (T-103A)			0.01/0.06	N/A	N/A	N/A	N/A	N/A	N/A
(c) EDC caustic wash tank (T-102)			0/0.002	N/A	N/A	N/A	N/A	N/A	N/A
(d) Steam stripper aqueous holding tank (T-110)			0.001/0.001	N/A	N/A	N/A	N/A	N/A	N/A

(continued)

TABLE 2-4. (continued)

Plant/location Process source[b]	Current control technology[b]	Current EDC/VOC control efficiency, %[b]	Current EDC/VOC emissions, Mg/yr[b]	Applicable additional controls	EDC/VOC emission reduction, Mg/yr[c]	Capital cost,[a,d,e] $	Net annual cost,[a,d,e] $	Cost effectiveness[f] EDC emissions, $/Mg	Cost effectiveness[f] VOC emissions, $/Mg
(e) Light ends column overhead accumulator (S-102)			0.002/0.222	N/A	N/A	N/A	N/A	N/A	N/A
(f) Heavy ends column overhead accumulator (S-103)			0.003/0.003	N/A	N/A	N/A	N/A	N/A	N/A
(g) EDC tar still column (C-104)			0/0	N/A	N/A	N/A	N/A	N/A	N/A
VCM manufacture (a) VCM tar stills column (C-204)			0/0	N/A	N/A	N/A	N/A	N/A	N/A
Ethyl Corporation, Baton Rouge, La. EDC manufacture (a) Incinerator vent	Incinerator/ scrubber	98/98[h]	2.2/10.2	N/A	N/A	N/A	N/A	N/A	N/A
Formosa, Baton Rouge, La. EDC/VCM manufacture (a) Incinerator	Incinerator	98/98[h]	38/204	N/A	N/A	N/A	N/A	N/A	N/A
Formosa, Point Comfort, Tex.[n] (a) Incinerator A	Incinerator	99.99/99.99	5.2/12.82	N/A	N/A	N/A	N/A	N/A	N/A
(b) Incinerator B	Incinerator	99.99/99.99	5.2/12.82	N/A	N/A	N/A	N/A	N/A	N/A
Georgia Pacific, Plaquemine, La. Vinyl chloride manufacture (a) IH-662 liquid incineration and IH-661 gas incineration (burning vents)			0.08/1.58	N/A	N/A	N/A	N/A	N/A	N/A
(b) IH-662 liquid incinerator			0.03/0.17	N/A	N/A	N/A	N/A	N/A	N/A
Olin Corporation[m] Lake Charles, La. Fire retardent	--	--	--	--	--	--	--	--	--
PPG Industries, Lake Charles, La. (a) No. 1 and No. 2 incinerator secondary scrubber stack	Incinerator	99.99/99.99	0.06/0.06	N/A	N/A	N/A	N/A	N/A	N/A
(b) No. 3 incinerator secondary scrubber	Incinerator	99.99/99.99	0.06/0.06	N/A	N/A	N/A	N/A	N/A	N/A
(c) No. 4 incinerator secondary scrubber stack	Incinerator	99.99/99.99	0.01/0.01	N/A	N/A	N/A	N/A	N/A	N/A

(continued)

TABLE 2-4. (continued)

Plant/location,[b] Process source	Current control technology[b]	Current EDC/VOC control efficiency, %[b]	Current EDC/VOC emissions,[g] Mg/yr	Applicable additional controls	EDC/VOC emission reduction,[c] Mg/yr	Capital cost,[a,d,e] $	Net annual cost,[a,d,e] $	Cost effectiveness[f] EDC emissions, $/Mg	Cost effectiveness[f] VOC emissions, $/Mg
Shell Chemical Co., Deer Park, Tex. VCM manufacture									
(a) A-1750 HCIN-2 incinerator	Incinerator	98/98[h]	22/55	N/A	N/A	N/A	N/A	N/A	N/A
(b) A-1770 HCIN-3 incinerator	Incinerator	98/98[h]	22/55	N/A	N/A	N/A	N/A	N/A	N/A
Union Carbide, Hahnville, La. Ethyleneamines I									
(a) Chlorides incinerator	Incinerator	99.9/99.9	0/0.02	N/A	N/A	N/A	N/A	N/A	N/A
Vulcan Chemicals, Geismar, La. PCE manufacture									
(a) EDC oxychlorination vent	Incinerator	98/98[h]	1.2/2.7	N/A	N/A	N/A	N/A	N/A	N/A
Vulcan Chemicals, Wichita, Kans. Grain fumigant blending									
(a) Blend tank vent			0.004/0.10	N/A	N/A	N/A	N/A	N/A	N/A

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[a] Calculated using CE Plant Cost Index (Chemical Engineering, June 11, 1984).
[b] Cited from information request.
[c] Reference No. 41 (98 percent efficiency).
[d] Reference No. 42.
[e] Reference No. 43.
[f] Annualized cost per unit of emission reduced.
[g] Incinerator stack EDC-9 (all process vent emissions are conveyed to the incinerator emission control system via closed system).
[h] Actual efficiency rate reported as >98 percent; however, insufficient data were available to verify the higher rate.
[i] N/A = Not applicable. No additional controls costed if existing removal efficiency ≥98 percent.
[j] Emissions estimated as average of similar plants.
[k] This vent contains no EDC.
[l] No further details provided.
[m] No process emissions.
[n] Data from Reference 44.

TABLE 2-5. VOC EMISSION FACTORS FROM EQUIPMENT LEAKS[a]

Equipment type	VOC emission factor	
	kg/d	Mg/yr
1. Pump seals		
• Packed	1.19	0.43
• Mechanical	1.19	0.43
• Double mechanical	0.0	0.0
2. Compressors	5.47	2.0
3. Flanges	0.02	0.01
4. Valves		
• Gas	0.13	0.05
• Liquid	0.17	0.06
5. Pressure relief devices		
• Gas	2.50	0.91
• Liquid	0.0	0.0
6. Sample connections		
• Gas	0.36	0.13
• Liquid	0.36	0.13
7. Open ended lines		
• Gas	0.04	0.15
• Liquid	0.04	0.15

[a] Reference 45.

TABLE 2-6. COSTS FOR IMPLEMENTATION OF CONTROLS FOR EDC FUGITIVE EMISSION SOURCES
First Quarter 1984 Dollars[a]

Plant/Location	Current control techniques[b,c]	Current control efficiency %[b]	Current EDC emissions Mg/yr[b]	Additional EDC emission reduction, Mg/yr[d]	Total capital cost, $[d]	Annualized cost, $[d]	EDC recovery credit, $[d,e]	Net annualized cost[f]	Cost effectiveness, $/Mg EDC[g]
Arco Chemical, Port Arthur, Tex.	N/A	N/A	20[h]	14	29,500	12,400	4,600	7,800	560
B. F. Goodrich, LaPorte, Tex.	N/A	N/A	200[h]	142	217,900	130,500	46,300	84,200	590
B. F. Goodrich, Calvert City, Ky.			144[h]	102	217,900	130,500	33,250	97,250	950
B. F. Goodrich, Convent, La.	N/A	N/A	2[h]	1.3	3,000	420	2,000	1,540	1,100
Borden, Geismar, La.	N/A	N/A	60[h]	43	65,400	39,200	14,000	25,200	590
Diamond Shamrock, Deer Park, Tex.	N/A	N/A	50[h]	36	84,500	58,700	11,700	47,000	1,300
Dow Chemical (Vinyl I Plant), Plaquemine, La.	l	0.80	360	260	864,700	340,000	84,000	255,200	980
Dow Chemical (Vinyl II Plant) Plaquemine, La.	N/A	N/A	100	75	141,000	97,300	24,500	72,800	970
Dow Chemical, Oyster Creek, Tex.	m	5.2	110	66	88,300	60,700	21,500	39,200	590
Dow Chemical, Texas Division	N/A	N/A	5	4	4,000	1,900	1,300	600	150
Dow Chemical, EDC Plant, Freeport, Tex.	N/A	N/A	21	16	13,000	14,000	5,200	8,800	550
Dow Chemical, 1-1,2, Trichloroethane Plant, Freeport, Tex.	N/A	N/A	8	6	6,300	4,900	2,000	2,900	480
Dow Chemical, Trichloro Plant Freeport, Tex.	N/A	N/A	9	8	3,800	5,700	2,600	3,100	390
E. I. duPont (Conoco), Westlake, La.		3.8	100	70	136,900	97,300	22,800	74,500	1,100
Ethyl Corporation, Baton Rouge, La.	p	7.5	46	27	18,700	14,900	8,800	6,100	230
Formosa, Point Comfort, Tex.	q	20	67	40	60,700	44,100	13,000	31,100	780
Formosa, Baton Rouge, La.	N/A	N/A	100	78	133,200	71,400	25,400	46,000	590
Georgia Pacific, Plaquemine La.	N/A	N/A	200	130	61,600	90,800	42,400	48,400	370
Olin Corporation, Lake Charles, La.	N/A	N/A	41	30	33,200	24,000	9,800	14,200	470
PPG Industries, Lake Charles, La.	N/A	N/A	64	46	102,500	71,200	15,000	56,200	1,200
Shell Chemical Co., Deer Park, Tex.	N/A	N/A	140	100	95,500	76,000	32,600	43,400	430
Union Carbide, Hahnville, La.	N/A	N/A	3	2	3,100	2,600	650	1,950	980
Vulcan Chemicals, Geismar, La.	N/A	N/A	44	29	50,800	35,100	9,400	25,700	890
Vulcan Chemicals, Wichita, Kans.	N/A	N/A	3	2	2,600	2,200	650	1,550	780

(continued)

TABLE 2-6. (continued)

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[a] Calculated using CE Plant Cost Index and M&S Equipment Cost Index (Chemical Engineering June 11, 1984).
[b] Information sited from Section 114 information request responses.
[c] Current control techniques were not listed if the technique or technology was judged to have 0 percent control efficiency.
[d] Based upon proposed emission control techniques and control efficiencies listed in Table 2-8.
[e] EDC valve ~$326/Mg First Quarter 1984 dollars, Reference No. 46.
[f] Annualized cost minus recovery credit.
[g] Net annualized cost per unit of emissions reduced.
[h] Emissions and costs estimated as average of similar plants.
[i]
[j]
[k]
[l] Pressure relief devices protected by rupture disc (100 percent efficiency).
[m] Rupture discs installed under 27 percent of relief devices in VOC or EDC liquid or vapor service (100 percent efficiency).
[n]
[o]
[p] Sample connections equipped with flow back loops (100 percent efficiency).
[q] Relief valves protected by rupture discs (100 percent efficiency).

TABLE 2-7. COSTS FOR IMPLEMENTATION OF CONTROLS FOR VOC FUGITIVE EMISSION SOURCES First Quarter 1984 Dollars[a]

Plant/Location	Current control techniques[b,c]	Current control efficiency %[b]	Current VOC emissions, Mg/yr[b]	Additional VOC emission reduction, Mg/yr[d]	Total capital cost, $[d]	Annualized cost, $[d]	EDC recovery credit, $[d,e,f]	Net annualized cost[g]	Cost effectiveness, $/Mg VOC[h]
Arco Chemical, Port Arthur, Tex.	N/A	N/A	29[i]	21	29,500	12,400	6,000	5,600	270
B. F. Goodrich, LaPorte, Tex.	N/A	N/A	345[i]	245	217,900	130,500	79,900	50,600	210
B. F. Goodrich, Calvert City, Ky.			249[i]	100	217,900	130,500	58,700	71,800	400
B. F. Goodrich, Convent, La.	N/A	N/A	4[i]	3	3,000	2,400	980	1,400	470
Borden, Geismer, La.	N/A	N/A	104[i]	75	65,400	39,200	24,450	14,750	200
Diamond Shamrock, Deer Park, Tex.	N/A	N/A	126[i]	90	84,500	58,700	29,300	29,400	330
Dow Chemical (Vinyl I Plant) Plaquemine, La.	m	0.80	580	420	864,700	340,000	136,900	203,100	400
Dow Chemical (Vinyl II Plant) Plaquemine, La.	N/A	N/A	210	150	141,000	97,300	48,900	48,400	320
Dow Chemical, Oyster Creek, Tex.	n	5.2	180	110	88,300	60,700	35,900	24,800	230
Dow Chemical, Texas Division	N/A	N/A	5	4	4,000	1,900	1,300	600	150
Dow Chemical, EDC Plant, Freeport, Tex.	N/A	N/A	38	30	13,000	14,000	9,800	4,200	140
Dow Chemical, 1-1,2, Trichloroethane Plant, Freeport, Tex.	N/A	N/A	14	11	6,300	4,900	3,600	1,300	120
Dow Chemical, Trichloro Plant, Freeport, Tex.	N/A	N/A	20	17	3,800	5,700	5,500	200	10
E. I. duPont (Conoco), Westlake, La.		38	170	110	136,900	97,300	35,900	61,400	560
Ethyl Corporation, Baton Rouge, La.	q	7.5	50	30	18,700	14,900	9,800	5,100	170
Formosa, Point Comfort, Tex.	o	20	120	70	60,700	44,100	22,800	21,300	300
Formosa, Baton Rouge, La.	N/A	N/A	160	120	133,200	71,400	39,100	32,300	270
Georgia Pacific, Plaquemine, La.	N/A	N/A	320	230	61,600	90,800	75,000	15,800	70
Olin Corporation, Lake Charles, La.	N/A	N/A	61	43	33,200	24,000	14,000	10,000	230
PPG Industries, Lake Charles, La.	N/A	N/A	150	110	102,500	71,200	35,900	35,300	320
Shell Chemical Co., Deer Park, Tex.	N/A	N/A	270	200	95,500	76,000	65,200	10,800	55
Union Carbide, Hanville, La.	N/A	N/A	3	2	3,100	2,600	650	1,950	900
Vulcan Chemicals, Geismar, La.	N/A	N/A	75	52	50,800	35,100	16,800	18,300	350
Vulcan Chemicals, Wichita, Kans.	N/A	N/A	5	4	2,600	2,200	1,300	900	230

(continued)

TABLE 2-7. (continued)

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[a] Calculated using CE Plant Cost Index and M&S Equipment Cost Index (Chemical Engineering June 11, 1984).
[b] Information sited from Section 114 information request responses.
[c] Current control techniques were not listed if the technique or technology was judged to have 0 percent control efficiency.
[d] Based upon proposed emission control techniques and control efficiencies listed in Table 2-8.
[e] EDC valve ~$326/Mg First Quarter 1984 dollars, Reference No. 46.
[f] Assumed VOC value = EDC value.
[g] Annualized cost minus recovery credit.
[h] Net annualized cost per unit of emissions reduced.
[i] Emissions and costs estimated as average of similar plants.
[j]
[k]
[l]
[m] Pressure relief devices protected by rupture disc (100 percent efficiency).
[n] Rupture discs installed under 27 percent of relief devices in VOC or EDC liquid or vapor service (100 percent efficiency).
[o]
[p]
[q] Sample connections equipped with flow back loops (100 percent efficiency).

TABLE 2-8. CONTROL TECHNIQUES AND COST FOR VOC/EDC FUGITIVE EMISSION SOURCES[a]
1984 Dollars

Equipment type	Control techniques	Percent reduction	Capital cost, $/component[b]	Annualized cost, $/component[b]
1. Pump seals				
· Packed	Monthly inspection	83.3	0	370
· Mechanical	Monthly inspection	83.3	0	370
· Double mechanical[c]	N/A[d]	N/A	N/A	N/A
2. Compressors	Degassing Reservoir vents	100	10,200	2,580
3. Flanges	None Available	N/A	N/A	N/A
4. Valves				
· Gas	Monthly inspection	70.3	0	20
· Liquid	Monthly inspection	72.5	0	20
5. Pressure relief devices				
· Gas	O-Ring	100	310	80
· Liquid[c]	N/A	N/A	N/A	N/A
6. Sample connections				
· Gas	Closed-purge sampling systems	100	670	170
· Liquid	Closed-purge sampling systems	100	670	170
7. Open ended lines				
· Gas	Caps on open ends	100	70	20
· Liquid	Caps on open ends	100	70	20

[a] Reference No. 47.

[b] Dollars updated using CE Plant Cost Index and M&S Equipment Cost Index (Chemical Engineering, June 11, 1984).

[c] Assume 0 emissions per year.

[d] Not applicable.

TABLE 2-9. EDC AND VOC EMISSION REDUCTION FROM FUGITIVE EMISSION SOURCES AS A FUNCTION OF COST EFFECTIVENESS

Cost-effectiveness range, $/Mg	No. of plants		Nationwide emission reduction, Mg/yr	
	EDC	VOC	EDC	VOC
0-500	7	22	300	2,280
500-1,000	14	2	930	110
1,000-2,000	3	0	120	0
TOTAL	24	24	1,350	2,390

TABLE 2-10. SECONDARY EDC EMISSION SOURCES

Plant/ Plant location/ Emission source	Current emissions, Mg/yr	Existing control technology	Applicable additional control technology	Capital and annual cost for additional control, $	Cost effectiveness additional control
Arco Chemicals Port Arthur, Tex.					
· Wastewater from steam stripper	0[a]		None	--[c]	--
· Disposal of spent drying media	0		None	--	--
B. F. Goodrich Calvert City, Ky.					
· Wastewater from steam stripper	0[d]		None	--	--
B. F. Goodrich Convent, La.					
· Wastewater from steam stripper	0[e]		None	--	--
B. F. Goodrich LaPorte, Tex.					
· Wastewater from steam stripper	0		None	--	--
Borden Geismar, La.	121[f]	-----------------NO ADDITIONAL DATA AVAILABLE-----------------			
Diamond Shamrock Deer Park, Tex.	0.40[f]	-----------------NO ADDITIONAL DATA AVAILABLE-----------------			

(continued)

TABLE 2-10. (continued)

Plant/ Plant location/ Emission source	Current emissions, Mg/yr	Existing control technology	Applicable additional control technology	Capital and annual cost for additional control, $	Cost effectiveness additional control
Dow Chemical Freeport, Tex.					
· Wastewater discharge	g		None	--	--
Dow Chemical Oyster Creek, Tex.					
· Treatment and disposal of wastewater, liquid wastes, or solid wastes	Negligible	i	None	--	--
Dow Chemical Plaquemine, La.					
· Liquid waste stream combustion (Vinyl I)	0	Incinerator	None	--	--
· Combustion device on materials recovery unit (Vinyl II)	0.05	Incinerator/vent scrubber	None	--	--
E. I. duPont Westlake, La.					
· Wastewater from steam stripper	17[j]		None	--	--
Ethyl Corp. Baton Rouge, La.					
· Wastewater aeration	9[k]	Steam stripper[b]	None	--	--

(continued)

TABLE 2-10. (continued)

Plant/ Plant location/ Emission source	Current emissions, Mg/yr	Existing control technology	Applicable additional control technology	Capital and annual cost for additional control, $	Cost effectiveness additional control
Formosa Corp.					
Baton Rouge, La.					
· Wastewater discharge	190	Steam stripper[b]	None	--	--
· Wastewater discharge	127	Steam stripper[b]	None	--	--
Formosa Corp.					
Point Comfort, Tex.					
· Wastewater discharge	122	Biosludge	Steam stripper	1	1
Georgia Pacific					
Plaquemine, La.					
· Wastewater from steam stripper	0[m]		None	--	--
· Liquid incineration	0		None	--	--
Olin Corp.					
Lake Charles, La.					
· Biological treatment pump wastewater	44[n]		Steam stripper	1	1
PPG Industries					
Lake Charles, La.					
· Emergency scrubber on steam stripper	14.9		None	--	--
· Incinerator on EDC recovery from steam stripper	0		None	--	--
· Wastewater discharge	0		None	--	--

(continued)

TABLE 2-10. (continued)

Plant/ Plant location/ Emission source	Current emissions, Mg/yr	Existing control technology	Applicable additional control technology	Capital and annual cost for additional control, $	Cost effectiveness additional control
Shell Chemical Deer Park, Tex.					
· Biological treatment of wastewater	1.1^p	None	Steam stripper	1	1
· Incineration of light and heavy ends, tars	0	Incinerator	None	--	--
Union Carbide Hahnville, La.					
· Incineration of waste liquids	0	Incinerator/scrubber	None	--	--
· Flush buggy vent	0	Incinerator	None	--	--
· Wastewater treatment	2.0	None	Stream stripper	1	1
Vulcan Chemicals Geismar, La.					
· Wastewater from steam stripper	0	Steam stripper^b	None	--	--
· Effluent from scrubber on tank vents	0^q	Deepwell injection	None	--	--

(continued)

TABLE 2-10. (continued)

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[a] Emissions from steam stripper are reported as zero. Any EDC dissolved in the wastewater after steam stripping may be emitted to the atmosphere after the water is discharged.

[b]

[c] -- = No control beyond steam stripping, scrubbing, or incineration costed.

[d] Wastewater to ponds is reported to contain less than 10 ppm EDC.

[e] Approximately 0.8 kg/d of EDC are contained in the water discharge.

[f] Emissions estimated as industry average based on similar sized plants.

[g] Wastewater discharge contains about 0.15 Mg/yr of EDC.

[h]

[i] No control reported.

[j] Plant reports that 96 percent of EDC contained in waste discharge is emitted to the air.

[k] Plant estimates that 50 percent of EDC contained in wastewater discharge is emitted to the air.

[l] Cost effectiveness exceeds \$2,500/Mg (\$2,260/ton) because of low EDC concentration.

[m] Emissions are reported to be zero (closed system).

[n] Wastewater discharge to biological treatment contains 87 Mg/yr of EDC. The fraction that is emitted was not reported and was assumed to be 50 percent.

[o] EDC content of waste discharge not reported.

[p] Plant reports that 98 percent of EDC contained in discharged wastewater is emitted to the air after discharge.

[q] Scrubber discharge contains about 0.2 Mg/yr.

TABLE 2-11. NATIONWIDE EDC STORAGE PATTERNS[a,b]

Tank type	No. of tanks	Nationwide emissions, Mg/yr EDC	Nationwide emissions, Mg/yr VOC
Fixed-roof	103	583.2	803.9
Internal floating roof	9	9.4	9.5
Pressure vessel	11	15.8	24.2
Open top	3	0.9	3.6
TOTAL	141	609.3	841.2

[a] Chemical industry only.

[b] Does not include Borden Chemical at Geismar, Louisiana, or Diamond Shamrock at Deer Park, Texas.

TABLE 2-12. CONTROLS USED ON EXISTING FIXED ROOF TANKS

Type	No. of tanks	Efficiency range, %
Thermal oxidation	25	98-99.99
Refrigeration	40	37-99.5
TOTAL	65	

TABLE 2-13. RETROFIT COSTS FOR WELDED STEEL INTERNAL FLOATING ROOFS
4th Quarter 1982 dollars

Item	Cost, $
1. Degassing[a]	Cost = $130.8\ V^{0.5132}$; or $1,000: whichever is greater where V = tank volume in cubic meters
2. Door sheet opening[a]	$1,300
3. Cost of the deck[b]	Cost ($1,000's) = 2.0 + 2.672D where D = tank diameter in meters
4. Cost of Teflon® primary seal[c]	$204 per meter of tank diameter
5. Cost of Viton® secondary seal[d]	$580 per meter of tank diameter

[a] Reference No. 48.
[b] Reference No. 49.
[c] Reference No. 27.
[d] Reference No. 28.

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TABLE 2-14. EDC EMISSIONS AND COST DATA FOR RETROFITTING FIXED-ROOF STORAGE TANKS WITH INTERNAL FLOATING-ROOFS (Primary Seals)
March 1984 Dollars[a]

Plant/location	Tank type[b,c]	Percent EDC stored	No. of storage tanks	Current control techniques[b]	Current control efficiency[b]	Current EDC emissions Mg/yr[d]	Total capital cost, $[e,f]	Annualized cost,[g] $	EDC emission Mg/yr reduction[h]	EDC recovery credits $[d,i]	Net annualized costs,[j] $	Cost effectiveness $/Mg[k]
Arco Port Arthur, Tex.						0.21	N/A	N/A	N/A	N/A	N/A	N/A
B. F. Goodrich Calvert City, Ky.						0.23	10,900	2,900	0.22	70	2,800	12,700
						2	77,500	20,400	1.9	620	19,800	10,400
						56	53,700	14,100	52	17,000	-2,900	-60
						4	15,600	4,100	4	1,300	2,800	700
						2	N/A	N/A	N/A	N/A	N/A	N/A
						0.18	14,600	3,000	0.20	70	3,700	18,500
						0.54	N/A	N/A	N/A	N/A	N/A	N/A
						0.10	N/A	N/A	N/A	N/A	N/A	N/A
						0.30	N/A	N/A	N/A	N/A	N/A	N/A
						0.90	N/A	N/A	N/A	N/A	N/A	N/A
						63	10,200	2,700	60	19,600	-16,900	-280
						46	67,100	17,600	43	14,000	3,600	80
						1	N/A	N/A	N/A	N/A	N/A	N/A
B. F. Goodrich Convent, La.						0	N/A	N/A	N/A	N/A	N/A	N/A
B. F. Goodrich LaPorte, Tex.						0	N/A	N/A	N/A	N/A	N/A	N/A
Borden Chemical[g] Geismar, La.	F	100	10	p	98	2.4	N/A	N/A	N/A	N/A	N/A	N/A
Diamond Shamrock[g] Deer Park, Tex.	F	100	10	p	98	5.8	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical EDC Plant Freeport, Tex.	F	56	2	r	87	3.4	34,000	8,900	3.20	1,000	7,900	2,500
	F	100	1	r	37	0.63	33,600	8,800	0.60	200	8,600	14,300
	F	5	1	s	67	0.04	33,000	8,700	0.04	13	8,700	217,500
	F	100	2	r	93	4.6	125,100	32,900	4.3	1,400	31,500	7,300
Dow Chemical 1,1,2 Trichloroethane Plant, Freeport, Tex.						0.20	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical[g] Trichlor Plant Freeport, Tex.						6	140,800	30,700	5	1,800	28,900	5,800
						0.08	140,800	30,600	0.08	25	30,600	402,900

(continued)

TABLE 2-14. (continued)

Plant/Location	Tank type^{b,c}	Percent EDC stored	No. of storage tanks	Current control tech-niques^{b}	Current control effi-ciency^{b}	Current EDC emissions Mg/yr^{d}	Total capital cost, $^{e,f}	Annual-ized cost,^{g} $	EDC emission Mg/yr reduction^{h}	EDC recovery credits $^{d,i}	Net annual-ized costs,^{j} $	Cost effect-iveness^{k} $/Mg
Dow Chemical Oyster Creek, Tex.	F	99	2	w	99	0.43	N/A	N/A	N/A	N/A	N/A	N/A
	F	76-99	1	w	99	0.23	N/A	N/A	N/A	N/A	N/A	N/A
	F	76-99	1	w	99	0.15	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical (Vinyl I) Plaquemine, La.	F	99	1	x	95	0.22	N/A	N/A	N/A	N/A	N/A	N/A
	F	99	1	x	95	0.80	N/A	N/A	N/A	N/A	N/A	N/A
	F	99	1	x	95	0.30	N/A	N/A	N/A	N/A	N/A	N/A
	F	99	1	x	95	0.77	N/A	N/A	N/A	N/A	N/A	N/A
	F	99	1	x	95	3.0	N/A	N/A	N/A	N/A	N/A	N/A
	F	99	1	x	95	2.1	N/A	N/A	N/A	N/A	N/A	N/A
	F	99	1	x	95	1.2	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical (Vinyl II) Plaquemine, La.	F	100	1	x	95	4.9	N/A	N/A	N/A	N/A	N/A	N/A
	F	100	2	x	95	3.5	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical Texas Division	F	99	1	r	99	0.40	N/A	N/A	N/A	N/A	N/A	N/A
DuPont (Conoco) Westlake, La.						21	114,400	27,000	20	6,500	20,500	1,000
						0	N/A	N/A	N/A	N/A	N/A	N/A
						0.008	N/A	N/A	N/A	N/A	N/A	N/A
						0	N/A	N/A	N/A	N/A	N/A	N/A
						0	N/A	N/A	N/A	N/A	N/A	N/A
						0.01	N/A	N/A	N/A	N/A	N/A	N/A
						0	N/A	N/A	N/A	N/A	N/A	N/A
						0	N/A	N/A	N/A	N/A	N/A	N/A
Ethyl Corp. Baton Rouge, La.	PV	99	2	l	0	3.5	11,500	3,000	3	1,000	2,000	700
	PV	99	1	p	99.9	0.04	N/A	N/A	N/A	N/A	N/A	N/A
	PV	50	1	y	0	3.0	10,600	2,800	2.7	900	1,900	700
	PV	99	1	p	99.9	0.01	N/A	N/A	N/A	N/A	N/A	N/A
Formosa Plastics Baton Rouge, La.	F	100	2	z	85	29	110,500	29,000	28	9,100	19,900	700
	F	100	1	aa	80	20	42,800	11,200	18	5,900	5,300	300
	F	99	1	p	99.9	0.25	N/A	N/A	N/A	N/A	N/A	N/A
	F	30	1	l	0	0.60	22,600	5,900	0.60	200	5,700	9,500
Formosa Point Comfort, Tex.	F	95-99	1	y	99	0.10	N/A	N/A	N/A	N/A	N/A	N/A
	F	99	1	y	99	0.26	N/A	N/A	N/A	N/A	N/A	N/A
	F	99	1	y	99	0.81	N/A	N/A	N/A	N/A	N/A	N/A
	F	100	1	y	99	1.0	N/A	N/A	N/A	N/A	N/A	N/A
	F	30-50	2	y	99	0.02	N/A	N/A	N/A	N/A	N/A	N/A

(continued)

TABLE 2-14. (continued)

Plant/location	Tank type^{b,c}	Percent EDC stored	No. of storage tanks	Current control tech-niques^{b}	Current control effi-ciency^{b}	Current EDC emissions Mg/yr^{d}	Total capital cost, $^{e,f}	Annual-ized cost,^{g} $	EDC emission Mg/yr reduction^{h}	EDC recovery credits $^{h,i}	Net annual-ized costs,^{j} $	Cost effect-iveness $/Mg^{k}
Georgia Pacific Plaquemine, La.						0.001	N/A	N/A	N/A	N/A	N/A	N/A
						0.001	N/A	N/A	N/A	N/A	N/A	N/A
						0	N/A	N/A	N/A	N/A	N/A	N/A
						0	N/A	N/A	N/A	N/A	N/A	N/A
						0.001	N/A	N/A	N/A	N/A	N/A	N/A
						0.001	N/A	N/A	N/A	N/A	N/A	N/A
						0.001	N/A	N/A	N/A	N/A	N/A	N/A
						0	N/A	N/A	N/A	N/A	N/A	N/A
						0.001	N/A	N/A	N/A	N/A	N/A	N/A
						0	N/A	N/A	N/A	N/A	N/A	N/A
Olin Corporation Lake Charles, La.						0	N/A	N/A	N/A	N/A	N/A	N/A
PPG Industries Lake Charles, La.	F	N/A	8	p	100	0	N/A	N/A	N/A	N/A	N/A	N/A
	F	N/A	3	bb	100	0	N/A	N/A	N/A	N/A	N/A	N/A
Shell Chemical Company Deer Park, Tex.	F	99	1	cc	99.99	0.008	N/A	N/A	N/A	N/A	N/A	N/A
	F	100	1	cc	99.99	0.001	N/A	N/A	N/A	N/A	N/A	N/A
	F	100	2	cc	99.99	0.005	N/A	N/A	N/A	N/A	N/A	N/A
	F	100	1	cc	99.99	0.01	N/A	N/A	N/A	N/A	N/A	N/A
	F	0-50	1	cc	99.99	0	N/A	N/A	N/A	N/A	N/A	N/A
	F	5-10	1	l	0	0.09	N/A	N/A	N/A	N/A	N/A	N/A
Union Carbide Taft, La.	F	100	1	dd	68	14	94,900	24,900	13	4,300	20,600	1,600
Vulcan Geismar, La.	F	100	1	l	0	0	13,300	3,500	7.5	2,500	1,000	130
	F	100	1	l	0	9.5	10,600	2,000	0.9	2,900	-100	-11
	F	100	3	l	0	3.3	21,900	5,700	3.1	1,000	4,700	1,500
	F	100	1	x	90	7	28,900	7,600	6.4	2,100	5,500	060
	F	100	1	x	90	3.5	101,100	26,600	3.3	1,100	25,500	7,700
	F	100	2	x	90	3.6	103,800	27,300	3.4	1,100	26,200	7,700
	F	100	1	x	90	7.5	113,000	29,700	7.0	2,300	27,400	3,900
Vulcan Chemicals Wichita, Kans.						0	N/A	N/A	N/A	N/A	N/A	N/A
						0	N/A	N/A	N/A	N/A	N/A	N/A

(continued)

TABLE 2-14. (continued)

[a] Calculated using CE Plant Cost Index and M&S Equipment Cost Index (Chemical Engineering June 11, 1984).
[b] Cited from Section 114 information request responses.
[c] Tank types.
F = Fixed roof.
CIF = Contact internal floating roof.
S = Spherical tank.
H = Horizontal tank.
HP = Horizontal pressure tank.
PV = Pressure vessel.
[d] Current storage tank emissions (per tank basis) based upon Section 114 information request responses.
[e] Refer to Table 2-13.
[f] Additional cost for the use of a Teflon coated primary seal ~$230/m (m = meter of diameter), Reference No. 27.
[g] Reference No. 50.
[h] Internal floating roof (primary seal only), 94 percent emission reduction efficiency.
[i] EDC value ~$320/Mg (First Quarter 1984 dollars), Reference No. 46.
[j] Annualized cost minus EDC recovery credits.
[k] Net annualized cost per unit of emissions reduced
[l]
[m]
[n]
[o]
[p] Incinerator.
[q] Estimated as industry average.
[r] Vent condenser.
[s] Vent scrubber.
[t]
[u]

[v]

[w] Mechanical refrigeration units and condensers.
[x] Refrigeration vapor recovery.
[y] Nitrogen blankets and incineration.
[z] Vapor recovery.
[aa] Conservation vents and inerts.
[bb] Refrigeration/recycle.
[cc] Compression and incineration.
[dd] Tank is nitrogen blanketed, submerged filled, insulated and refrigerated.
[ee]

TABLE 2-15. EDC EMISSION REDUCTION FROM FIXED ROOF TANKS AS A FUNCTION OF COST EFFECTIVENESS

Cost effectiveness range, $/Mg	No. of tanks	Nationwide emission reduction, Mg EDC/yr[a]
Credit	7	345
0-100	1	43
100-500	2	26
500-1,000	8	95
1,000-2,000	4	22
>2,000	18	41
TOTAL	40	572

[a] Based on welded, contact internal floating roof with primary seals only.

TABLE 2-16. FIXED ROOF TANK SUMMARY

EDC emission range, Mg/yr	No. of tanks	Percent of tanks	EDC emissions, Mg/yr	Percent of emissions	Emission reduction, Mg/yr[a]
0-1	70	56	8	1	2
1-10	42	34	175	26	84
10-20	2	2	34	5	31
>20	10	8	461	68	455
Total	124	100	678	100	572

[a] Based on welded contact internal floating roof with primary seals only.

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TABLE 2-17. VOC EMISSIONS AND COST DATA FOR RETROFITTING FIXED-ROOF STORAGE TANKS WITH INTERNAL FLOATING-ROOFS (Primary Seals) March 1984 Dollars[a]

	Tank type[b,c]	No. of storage tanks	Current control techniques[b]	Current control efficiency[b]	Current VOC emissions, Mg/yr[d]	Total capital cost, $[e,f]	Annualized cost,[g] $	VOC emission Mg/yr reduction[h]	VOC recovery credits, $[i,j]	Net annualized costs,[k] $	Cost effectiveness $/Mg[l]
Arco Port Arthur, Tex.					0.21	N/A	N/A	N/A	N/A	N/A	N/A
B. F. Goodrich Calvert City, Ky.					12	10,900	2,900	11	3,600	-700	-65
					100	77,500	20,400	94	30,600	-10,200	-110
					57	53,700	14,100	54	17,600	-3,500	-65
					4	15,600	4,100	4.0	1,300	2,800	700
					2	N/A	N/A	N/A	N/A	N/A	N/A
					0.72	14,600	3,800	0.70	230	3,600	5,100
					2.0	N/A	N/A	N/A	N/A	N/A	N/A
					0.40	N/A	N/A	N/A	N/A	N/A	N/A
					1.2	N/A	N/A	N/A	N/A	N/A	N/A
					0.95	N/A	N/A	N/A	N/A	N/A	N/A
					64	10,200	2,700	60	19,600	-16,900	-280
					46	67,100	17,600	44	14,200	3,400	80
					1.0	N/A	N/A	N/A	N/A	N/A	N/A
B. F. Goodrich Convent, La.					0	N/A	N/A	N/A	N/A	N/A	N/A
B. F. Goodrich LaPorte, Tex.					0	N/A	N/A	N/A	N/A	N/A	N/A
Borden Chemical[r] Geismar, La.	F	10	q	90	2.4	N/A	N/A	N/A	N/A	N/A	N/A
Diamond Shamrock[r] Deer Park, Tex.	F	10	q	98	5.8	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical EDC Plant Freeport, Tex.	F	2	s	87	6.0	34,000	8,900	5	1,800	7,100	1,300
	F	1	s	37	0.63	31,600	8,800	0.60	200	8,600	14,300
	F	1	t	67	0.80	33,000	8,700	0.75	250	11,300	10,500
	F	2	s	93	4.6	125,100	32,900	4	1,400	31,500	7,300
Dow Chemical 1,1,2 Trichloroethane Plant, Freeport, Tex.					0.20	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical[v] Trichlor Plant Freeport, Tex.					11	140,000	30,700	10	3,300	27,400	2,700
					0.16	140,000	30,600	0.16	50	30,600	191,300

(continued)

TABLE 2-17. (continued)

	Tank type[b,c]	No. of storage tanks	Current control techniques[b]	Current control efficiency[b]	Current VOC emissions, Mg/yr[d]	Total capital cost, $[e,f]	Annualized cost,[g] $	VOC emission Mg/yr reduction[h]	VOC recovery credits, $[i,j]	Net annualized costs,[k] $	Cost effectiveness $/Mg[l]
Dow Chemical Oyster Creek, Tex.	F	2	x	99	0.43	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	x	99	0.23	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	x	99	0.15	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical (Vinyl I) Plaquemine, La.	F	1	y	95	0.22	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	y	95	0.81	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	y	95	0.30	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	y	95	0.78	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	y	95	2.0	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	y	95	2.1	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	y	95	1.8	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical (Vinyl II) Plaquemine, La.	F	1	y	95	4.9	N/A	N/A	N/A	N/A	N/A	N/A
	F	2	y	95	3.5	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical Texas Division	F	1	s	99	0.40	N/A	N/A	N/A	N/A	N/A	N/A
DuPont (Conoco) Westlake, La.					21	114,400	27,000	20	6,500	20,500	1,000
					0	N/A	N/A	N/A	N/A	N/A	N/A
					0.008	N/A	N/A	N/A	N/A	N/A	N/A
					0	N/A	N/A	N/A	N/A	N/A	N/A
					0	N/A	N/A	N/A	N/A	N/A	N/A
					0.01	N/A	N/A	N/A	N/A	N/A	N/A
					0	N/A	N/A	N/A	N/A	N/A	N/A
					0	N/A	N/A	N/A	N/A	N/A	N/A
Ethyl Corp. Baton Rouge, La.	PV	2	m	0	3.5	11,500	3,000	3	1,100	1,900	580
	PV	1	q	99.9	0.04	N/A	N/A	N/A	N/A	N/A	N/A
	PV	1	z	0	6	10,600	2,800	5.5	1,800	1,000	180
	PV	1	q	99.9	0.01	N/A	N/A	N/A	N/A	N/A	N/A
Formosa Plastics Baton Rouge, La.	F	2	aa	85	29	110,500	29,000	28	9,000	20,000	700
	F	1	bb	80	20	42,800	11,200	18	6,000	5,200	300
	F	1	q	99.9	0.3	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	m	0	2.0	22,600	5,900	1.9	620	5,300	2,800
Formosa Point Comfort, Tex.	F	1	z	99	0.10	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	z	99	0.26	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	z	99	0.02	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	z	99	1.0	N/A	N/A	N/A	N/A	N/A	N/A
	F	2	z	99	0.04	N/A	N/A	N/A	N/A	N/A	N/A

(continued)

TABLE 2-17. (continued)

	Tank type[b,c]	No. of storage tanks	Current control tech- niques[b]	Current control effi- ciency[b]	Current VOC emissions, Mg/yr[d]	Total capital cost, $[e,f]	Annual- ized cost,[g] $	VOC emission Mg/yr reduction[h]	VOC recovery credits, $[i,j]	Net annual- ized costs,[k] $	Cost effect- iveness $/Mg[l]
Georgia Pacific Plaquemine, La.					0.001	N/A	N/A	N/A	N/A	N/A	N/A
					0.001	N/A	N/A	N/A	N/A	N/A	N/A
					0	N/A	N/A	N/A	N/A	N/A	N/A
					0	N/A	N/A	N/A	N/A	N/A	N/A
					0.001	N/A	N/A	N/A	N/A	N/A	N/A
					0.001	N/A	N/A	N/A	N/A	N/A	N/A
					0.001	N/A	N/A	N/A	N/A	N/A	N/A
					0	N/A	N/A	N/A	N/A	N/A	N/A
					0.001	N/A	N/A	N/A	N/A	N/A	N/A
					0	N/A	N/A	N/A	N/A	N/A	N/A
Olin Corporation Lake Charles, La.					0	N/A	N/A	N/A	N/A	N/A	N/A
PPG Industries Lake Charles, La.	F	8	q	100	0	N/A	N/A	N/A	N/A	N/A	N/A
	F	3	cc	100	0	N/A	N/A	N/A	N/A	N/A	N/A
Shell Chemical Company Deer Park, Tex.	F	1	dd	99.99	0.008	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	dd	99.99	0.001	N/A	N/A	N/A	N/A	N/A	N/A
	F	2	dd	99.99	0.005	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	dd	99.99	0.01	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	dd	99.99	0	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	m	0	0.90	N/A	N/A	N/A	N/A	N/A	N/A
Union Carbide Taft, La.	F	1	ee	68	14	94,900	24,900	13	4,300	20,600	1,600
Vulcan Geismar, La.	F	1	m	0	8	13,300	3,500	7.5	2,500	1,000	140
	F	1	m	0	9.5	10,600	2,800	9	2,900	-100	-10
	F	3	m	0	3.3	21,900	5,700	3	1,000	4,700	1,600
	F	1	y	90	7.0	20,900	7,600	6.4	2,100	5,500	860
	F	1	y	90	3.5	101,100	26,600	3.3	1,100	25,500	7,600
	F	2	y	90	3.6	103,800	27,300	3.4	1,100	26,200	7,700
	F	1	y	90	7.5	113,000	29,700	7.0	2,300	27,400	3,900
Vulcan Chemicals Wichita, Kans.					0	N/A	N/A	N/A	N/A	N/A	N/A
					0	N/A	N/A	N/A	N/A	N/A	N/A

(continued)

TABLE 2-17. (continued)

[a] Calculated using CE Plant Cost Index and M&S Equipment Cost Index (Chemical Engineering June 11, 1984).

[b] Cited from Section 114 information request responses.

[c] Tank types.
F = Fixed roof.
CIF = Contact internal floating roof.
S = Spherical tank.
H = Horizontal tank.
HP = Horizontal pressure tank.
PV = Pressure vessel.

[d] Current storage tank emissions (per tank basis) based upon Section 114 information request responses.

[e] Refer to Table 2-13.

[f] Additional cost for the use of a Teflon coated primary seal ~$230/m (m = meter of diameter), Reference No. 27.

[g] Reference No. 50.

[h] Internal floating roof (primary seal only), 94 percent emission reduction efficiancy.

[i] EDC value ~$326/Mg (First Quarter 1984 dollars), Reference No. 46.

[j] Assumed VOC value equal to EDC value.

[k] Annualized cost minus EDC recovery credits.

[l] Net annualized cost per unit of emissions reduced.

[m]

[n]

[o]

[p]

[q] Incinerator.

[r] Estimated as industry average.

[s] Vent condenser.

[t] Vent scrubber.

[u]

[v]

[w]

[x] Mechanical refrigeration units and condensers.

[y] Refrigeration vapor recovery.

[z] Nitrogen blankets and incineration.

[aa] Vapor recovery.

[bb] Conservation vents and inerts.

[cc] Refrigeration/recycle.

[dd] Compression and incineration.

[ee] Tank is nitrogen blanketed, submerged filled, insulated and refrigerated.

[ff]

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TABLE 2-18. EDC EMISSIONS AND COST DATA FOR RETROFITTING FIXED-ROOF STORAGE TANKS WITH INTERNAL FLOATING-ROOFS (Primary and Secondary Seals) March 1984 Dollars[d]

Plant/location	Tank type[b,c]	Percent EDC stored	No. of storage tanks	Current control tech-niques[b]	Current control effi-ciency[b]	Current EDC emissions Mg/yr[a]	Total capital cost, $[e,f,g]	Annual-ized cost,[h] $	EDC emission Mg/yr reduction[i]	EDC recovery credits $[e,j]	Net annual-ized costs,[k] $	Cost effect-iveness $/Mg[l]
Arco Port Arthur, Tex.						0.21	N/A	N/A	N/A	N/A	N/A	N/A
B. F. Goodrich Calvert City, Ky.						0.23	12,100	3,200	0.22	70	3,100	14,100
						2	91,900	25,500	1.9	600	24,900	13,100
						56	56,500	16,500	54	17,600	-1,100	-20
						4	17,700	4,700	4	1,300	3,400	850
						2	N/A	N/A	N/A	N/A	N/A	N/A
						0.18	16,900	4,700	0.17	60	4,600	27,100
						0.54	N/A	N/A	N/A	N/A	N/A	N/A
						0.10	N/A	N/A	N/A	N/A	N/A	N/A
						0.30	N/A	N/A	N/A	N/A	N/A	N/A
						0.90	N/A	N/A	N/A	N/A	N/A	N/A
						63	11,500	3,000	61	19,900	-16,900	-280
						46	78,100	20,500	45	14,700	15,000	330
						1	N/A	N/A	N/A	N/A	N/A	N/A
B. F. Goodrich Convent, La.						0	N/A	N/A	N/A	N/A	N/A	N/A
B. F. Goodrich LaPorte, Tex.						0	N/A	N/A	N/A	N/A	N/A	N/A
Borden Chemical[f] Geismar, La.	f	100	10	q	98	2.4	N/A	N/A	N/A	N/A	N/A	N/A
Diamond Shamrock[f] Deer Park, Tex.	f	100	10	q	98	5.8	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical EDC Plant Freeport, Tex.	f	56	2	s	87	3.4	40,000	10,500	3.3	1,100	9,400	2,900
	f	100	1	s	37	0.63	39,100	10,300	0.61	200	10,100	16,600
	f	5	1	t	67	0.04	39,000	10,250	0.04	15	10,250	256,300
	f	100	2	s	93	4.6	149,100	39,200	4.5	1,500	37,700	8,400
Dow Chemical 1,1,2 Trichloroethane Plant, Freeport, Tex.						0.20	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical[v] Trichlor Plant Freeport, Tex.						6	N/A	N/A	N/A	N/A	N/A	N/A
						0.08	N/A	N/A	N/A	N/A	N/A	N/A

(continued)

TABLE 2-18. (continued)

Plant/location	Tank type^{b,c}	Percent EDC stored	No. of storage tanks	Current control techniques^{b}	Current control efficiency^{b}	Current EDC emissions Mg/yr^{d}	Total capital cost, \$^{e,f,g}	Annualized cost,^{h} \$	EDC emission Mg/yr reduction^{i}	EDC recovery credits \$^{e,j}	Net annualized costs,^{k} \$	Cost effectiveness \$/Mg^{l}
Dow Chemical Oyster Creek, Tex.	F	99	2	x	99	0.43	N/A	N/A	N/A	N/A	N/A	N/A
	F	76-99	1	x	99	0.23	N/A	N/A	N/A	N/A	N/A	N/A
	F	76-99	1	x	99	0.15	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical (Vinyl I) Plaquemine, La.	F	99	1	y	95	0.22	N/A	N/A	N/A	N/A	N/A	N/A
	F	99	1	y	95	0.80	N/A	N/A	N/A	N/A	N/A	N/A
	F	99	1	y	95	0.30	N/A	N/A	N/A	N/A	N/A	N/A
	F	99	1	y	95	0.77	N/A	N/A	N/A	N/A	N/A	N/A
	F	99	1	y	95	3.0	N/A	N/A	N/A	N/A	N/A	N/A
	F	99	1	y	95	2.1	N/A	N/A	N/A	N/A	N/A	N/A
	F	99	1	y	95	1.2	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical (Vinyl II) Plaquemine, La.	F	100	1	y	95	4.9	N/A	N/A	N/A	N/A	N/A	N/A
	F	100	2	y	95	3.5	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical Texas Division	F	99	1	s	99	0.40	N/A	N/A	N/A	N/A	N/A	N/A
DuPont (Conoco) Westlake, La.						21	121,100	35,400	20.4	6,700	28,700	1,400
						0	N/A	N/A	N/A	N/A	N/A	N/A
						0.008	N/A	N/A	N/A	N/A	N/A	N/A
						0	N/A	N/A	N/A	N/A	N/A	N/A
						0	N/A	N/A	N/A	N/A	N/A	N/A
						0.01	N/A	N/A	N/A	N/A	N/A	N/A
						0	N/A	N/A	N/A	N/A	N/A	N/A
						0	N/A	N/A	N/A	N/A	N/A	N/A
Ethyl Corp. Baton Rouge, La.	PV	99	2	m	0	3.5	13,000	3,400	3.4	1,100	2,300	680
	PV	99	1	q	99.9	0.04	N/A	N/A	N/A	N/A	N/A	N/A
	PV	50	1	z	0	3.0	11,900	3,100	2.8	900	2,200	790
	PV	99	1	q	99.9	0.01	N/A	N/A	N/A	N/A	N/A	N/A
Formosa Plastics Baton Rouge, La.	F	100	2	aa	85	29	129,900	34,100	28.5	9,300	24,800	870
	F	100	1	bb	80	20	49,900	13,100	19	6,200	6,900	360
	F	99	1	q	99.9	0.25	N/A	N/A	N/A	N/A	N/A	N/A
	F	30	1	m	0	0.60	26,500	7,000	0.6	200	6,800	11,300
Formosa Point Comfort, Tex.	F	95-99	1	z	99	0.10	N/A	N/A	N/A	N/A	N/A	N/A
	F	99	1	z	99	0.26	N/A	N/A	N/A	N/A	N/A	N/A
	F	99	1	z	99	0.01	N/A	N/A	N/A	N/A	N/A	N/A
	F	100	1	z	99	1.0	N/A	N/A	N/A	N/A	N/A	N/A
	F	30-50	2	z	99	0.02	N/A	N/A	N/A	N/A	N/A	N/A

(continued)

TABLE 2-18. (continued)

Plant/location	Tank type[b,c]	Percent EDC stored	No. of storage tanks	Current control techniques[b]	Current control efficiency[b]	Current EDC emissions Mg/yr[d]	Total capital cost, $[e,f,g]	Annualized cost,[h] $	EDC emission Mg/yr reduction[i]	EDC recovery credits $[a,j]	Net annualized costs,[k] $	Cost effectiveness $/Mg[l]
Georgia Pacific Plaquemine, La.						0.001	N/A	N/A	N/A	N/A	N/A	N/A
						0.001	N/A	N/A	N/A	N/A	N/A	N/A
						0	N/A	N/A	N/A	N/A	N/A	N/A
						0	N/A	N/A	N/A	N/A	N/A	N/A
						0.001	N/A	N/A	N/A	N/A	N/A	N/A
						0.001	N/A	N/A	N/A	N/A	N/A	N/A
						0.001	N/A	N/A	N/A	N/A	N/A	N/A
						0	N/A	N/A	N/A	N/A	N/A	N/A
						0.001	N/A	N/A	N/A	N/A	N/A	N/A
						0	N/A	N/A	N/A	N/A	N/A	N/A
Olin Corporation Lake Charles, La.						0	N/A	N/A	N/A	N/A	N/A	N/A
PPG Industries Lake Charles, La.	F	N/A	8	q	100	0	N/A	N/A	N/A	N/A	N/A	N/A
	F	N/A	3	cc	100	0	N/A	N/A	N/A	N/A	N/A	N/A
Shell Chemical Company Deer Park, Tex.	F	99	1	dd	99.99	0.008	N/A	N/A	N/A	N/A	N/A	N/A
	F	100	1	dd	99.99	0.001	N/A	N/A	N/A	N/A	N/A	N/A
	F	100	2	dd	99.99	0.005	N/A	N/A	N/A	N/A	N/A	N/A
	F	100	1	dd	99.99	0.01	N/A	N/A	N/A	N/A	N/A	N/A
	F	0-50	1	dd	99.99	0	N/A	N/A	N/A	N/A	N/A	N/A
	F	5-10	1	m	0	0.09	N/A	N/A	N/A	N/A	N/A	N/A
Union Carbide Taft, La.	F	100	1	ee	68	14	113,300	29,800	13.6	4,400	25,400	1,900
Vulcan Geismar, La.	F	100	1	m	0	8	15,100	4,000	7.7	2,500	1,500	200
	F	100	1	m	0	9.5	11,900	3,100	9.2	3,000	100	10
	F	100	3	m	0	3.3	25,700	6,800	3.2	1,000	5,800	1,800
	F	100	1	y	90	7	33,700	8,900	6.6	2,200	6,700	1,000
	F	100	1	y	90	3.5	121,100	31,800	3.4	1,100	30,700	9,000
	F	100	2	y	90	3.6	124,400	32,700	3.5	1,100	31,600	9,000
	F	100	1	y	90	7.5	135,000	35,500	7.3	2,400	33,100	4,500
Vulcan Chemicals Wichita, Kans.						0	N/A	N/A	N/A	N/A	N/A	N/A
						0	N/A	N/A	N/A	N/A	N/A	N/A

(continued)

TABLE 2-18. (continued)

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[a] Calculated using CE Plant Cost Index and M&S Equipment Cost Index (Chemical Engineering June 11, 1984).

[b] Cited from Section 114 information request responses.

[c] Tank types.

F = Fixed roof.
CIF = Contact internal floating roof.
S = Spherical tank.
H = Horizontal tank.
HP = Horizontal pressure tank.
PV = Pressure vessel.

[d] Current storage tank emissions (per tank basis) based upon Section 114 information request responses.

[e] Refer to Table 2-13.

[f] Additional cost for the use of a Teflon coated primary seal ~$230/m (m = meter of diameter), Reference No. 27.

[g] Cost for a Viton® coated secondary seal ~656/m (m = meters of diameter) 1st Quarter 1984 dollars, Reference No. 28.

[h] Reference No. 50.

[i] Internal floating roof (primary and secondary seal), 97 percent emission reduction efficiency.

[j] EDC value ~$326/Mg (First Quarter 1984 dollars), Reference No. 46.

[k] Annualized cost minus EDC recovery credits.

[l] Net annualized cost per unit of emissions reduced.

[m]

[n]

[o]

[p]

[q] Incinerator.

[r] Estimated as industry average.

[s] Vent condenser.

[t] Vent scrubber.

[u]

[v]

[w]

[x] Mechanical refrigeration units and condensers.

[y] Refrigeration vapor recovery.

[z] Nitrogen blankets and incineration.

[aa] Vapor recovery.

[bb] Conservation vents and inerts.

[cc] Refrigeration/recycle.

[dd] Compression and incineration.

[ee] Tank is nitrogen blanketed, submerged filled, insulated and refrigerated.

[ff]

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TABLE 2-19. VOC EMISSIONS AND COST DATA FOR RETROFITTING FIXED-ROOF STORAGE TANKS WITH INTERNAL FLOATING-ROOFS (Primary and Secondary Seals) March 1984 Dollars[a]

	Tank type[b,c]	No. of storage tanks[d]	Current control techniques	Current control efficiency	Current VOC emissions, Mg/yr[d]	Total capital cost, $[e,f,g]	Annualized cost,[h] $	VOC emission Mg/yr reduction[i]	VOC recovery credits, $[j,k]	Net annualized costs,[l] $	Cost effectiveness $/Mg[m]
Arco Port Arthur, Tex.[e]					0.21	N/A	N/A	N/A	N/A	N/A	N/A
B. F. Goodrich Calvert City, Ky.					12	12,100	3,200	11.6	3,800	-600	-50
					100	91,900	25,500	97	31,600	-6,100	-60
					57	56,500	16,500	55	10,000	-1,500	-30
					4	17,700	4,700	3.9	1,300	3,400	870
					2	N/A	N/A	N/A	N/A	N/A	N/A
					0.72	16,900	4,700	0.70	230	4,500	6,400
					2.0	N/A	N/A	N/A	N/A	N/A	N/A
					0.40	N/A	N/A	N/A	N/A	N/A	N/A
					1.2	N/A	N/A	N/A	N/A	N/A	N/A
					0.95	N/A	N/A	N/A	N/A	N/A	N/A
					64	11,500	3,000	62	20,200	-17,200	-280
					46	70,100	20,500	45	14,700	5,800	130
					1.0	N/A	N/A	N/A	N/A	N/A	N/A
B. F. Goodrich Convent, La.					0	N/A	N/A	N/A	N/A	N/A	N/A
B. F. Goodrich LaPorte, Tex.					0	N/A	N/A	N/A	N/A	N/A	N/A
Borden Chemical[s] Geismar, La.	f	10	r	98	2.4	N/A	N/A	N/A	N/A	N/A	N/A
Diamond Shamrock[s] Deer Park, Tex.	f	10	r	98	5.8	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical EDC Plant Freeport, Tex.	f	2	t	87	6	40,000	10,500	5.8	1,900	8,600	1,500
	f	1	t	37	0.63	39,100	10,300	0.61	200	10,100	16,600
	f	1	u	67	0.80	39,000	10,250	0.78	250	10,000	12,800
	f	2	t	93	4.6	149,100	39,200	4.5	1,500	37,700	8,400
Dow Chemical 1,1,2 Trichloroethane Plant, Freeport, Tex.					0.20	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical[w] Trichlor Plant Freeport, Tex.					11	N/A	N/A	N/A	N/A	N/A	N/A
					0.16	N/A	N/A	N/A	N/A	N/A	N/A

(continued)

TABLE 2-19. (continued)

	Tank type^{b,c}	No. of storage tanks^{d}	Current control techniques	Current control efficiency	Current VOC emissions, Mg/yr^{d}	Total capital cost, \$^{e,f,g}	Annualized cost,^{h} \$	VOC emission Mg/yr reduction^{i}	VOC recovery credits,^{j,k} \$	Net annualized costs,^{l} \$	Cost effectiveness \$/Mg^{m}
Dow Chemical Oyster Creek, Tex.	F	2	y	99	0.43	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	y	99	0.23	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	y	99	0.15	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical (Vinyl I) Plaquemine, La.	F	1	z	95	0.22	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	z	95	0.81	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	z	95	0.30	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	z	95	0.78	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	z	95	3.0	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	z	95	2.1	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	z	95	3.8	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical (Vinyl II) Plaquemine, La.	F	1	z	95	4.9	N/A	N/A	N/A	N/A	N/A	N/A
	F	2	z	95	3.5	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical Texas Division	F	1	t	99	0.40	N/A	N/A	N/A	N/A	N/A	N/A
DuPont (Conoco) Westlake, La.					21	121,100	35,400	20.4	6,700	28,700	1,400
					0	N/A	N/A	N/A	N/A	N/A	N/A
					0.008	N/A	N/A	N/A	N/A	N/A	N/A
					0	N/A	N/A	N/A	N/A	N/A	N/A
					0	N/A	N/A	N/A	N/A	N/A	N/A
					0.01	N/A	N/A	N/A	N/A	N/A	N/A
					0	N/A	N/A	N/A	N/A	N/A	N/A
					0	N/A	N/A	N/A	N/A	N/A	N/A
Ethyl Corp. Baton Rouge, La.	PV	2	n	0	3.5	13,000	3,400	3.4	1,100	2,300	680
	PV	1	r	99.9	0.04	N/A	N/A	N/A	N/A	N/A	N/A
	PV	1	aa	0	6	11,900	3,100	5.8	1,900	1,200	200
	PV	1	r	99.9	0.01	N/A	N/A	N/A	N/A	N/A	N/A
Formosa Plastics Baton Rouge, La.	F	2	bb	85	29	129,900	34,100	28.5	9,300	24,800	870
	F	1	cc	80	20	49,900	13,100	19	6,200	6,900	360
	F	1	r	99.9	0.3	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	n	0	2.0	26,500	7,000	1.9	600	6,400	3,400
Formosa Point Comfort, Tex.	F	1	aa	99	0.10	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	aa	99	0.26	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	aa	99	0.82	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	aa	99	1.0	N/A	N/A	N/A	N/A	N/A	N/A
	F	2	aa	99	0.04	N/A	N/A	N/A	N/A	N/A	N/A

(continued)

TABLE 2-19. (continued)

	Tank type[b,c]	No. of storage tanks[d]	Current control techniques	Current control efficiency	Current VOC emissions, Mg/yr[d]	Total capital cost, $[e,f,g]	Annualized cost,[h] $	VOC emission Mg/yr reduction[i]	VOC recovery credits, $[j,k]	Net annualized costs,[l] $	Cost effectiveness $/Mg[m]
Georgia Pacific Plaquemine, La.					0.001	N/A	N/A	N/A	N/A	N/A	N/A
					0.001	N/A	N/A	N/A	N/A	N/A	N/A
					0	N/A	N/A	N/A	N/A	N/A	N/A
					0	N/A	N/A	N/A	N/A	N/A	N/A
					0.001	N/A	N/A	N/A	N/A	N/A	N/A
					0.001	N/A	N/A	N/A	N/A	N/A	N/A
					0.001	N/A	N/A	N/A	N/A	N/A	N/A
					0	N/A	N/A	N/A	N/A	N/A	N/A
					0.001	N/A	N/A	N/A	N/A	N/A	N/A
					0	N/A	N/A	N/A	N/A	N/A	N/A
Olin Corporation Lake Charles, La.					0	N/A	N/A	N/A	N/A	N/A	N/A
PPG Industries Lake Charles, La.	F	8	r	100	0	N/A	N/A	N/A	N/A	N/A	N/A
	F	3	dd	100	0	N/A	N/A	N/A	N/A	N/A	N/A
Shell Chemical Company Deer Park, Tex.	F	1	ee	99.99	0.000	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	ee	99.99	0.001	N/A	N/A	N/A	N/A	N/A	N/A
	F	2	ee	99.99	0.005	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	ee	99.99	0.01	N/A	N/A	N/A	N/A	N/A	N/A
	F	1	ee	99.99	0	N/A	N/A	N/A	N/A	N/A	N/A
	F	3	n	0	0.90	N/A	N/A	N/A	N/A	N/A	N/A
Union Carbide Taft, La.	F	1	ff	60	14	113,300	29,000	13.6	4,400	25,400	1,900
Vulcan Geismar, La.	F	1	n	0	0	15,100	4,000	7.8	2,500	1,400	100
	F	1	n	0	9.5	11,900	3,100	9.2	3,000	130	15
	F	3	n	0	3.3	25,700	6,000	3.2	1,000	5,000	1,800
	F	1	z	90	7.0	33,700	8,900	6.8	2,200	6,700	1,000
	F	1	z	90	3.5	121,100	31,000	3.4	1,100	30,700	9,000
	F	2	z	90	3.6	124,400	32,700	3.5	1,100	31,600	9,000
	F	1	z	90	7.5	135,000	35,500	7.3	2,400	33,100	4,500
Vulcan Chemicals Wichita, Kans.					0	N/A	N/A	N/A	N/A	N/A	N/A
					0	N/A	N/A	N/A	N/A	N/A	N/A

(continued)

TABLE 2-19. (continued)

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[a] Calculated using CE Plant Cost Index and M&S Equipment Cost Index (Chemical Engineering June 11, 1984).

[b] Cited from Section 114 information request responses.

[c] Tank types.

F = Fixed roof.
CIF = Contact internal floating roof.
S = Spherical tank.
H = Horizontal tank.
HP = Horizontal pressure tank.
PV = Pressure vessel.

[d] Current storage tank emissions (per tank basis) based upon Section 114 information request responses.

[e] Refer to Table 2-13.

[f] Additional cost for the use of a Teflon coated primary seal ~$230/m (m = meter of diameter), Reference No. 27.

[g] Cost for a Viton® coated secondary seal ~656/m (m = meters of diameter) 1st Quarter 1984 dollars, Reference No. 28.

[h] Reference No. 50.

[i] Internal floating roof (primary and secondary seal), 97 percent emission reduction efficiency.

[j] Assumed VOC value equal to EDC value.

[k] EDC value ~$326/Mg (First Quarter 1984 dollars), Reference No. 46.

[l] Annualized cost minus EDC recovery credits.

[m] Net annualized cost per unit of emissions reduced.

[n]

[o]

[p]

[q]

[r] Incinerator.

[s] Estimated as industry average.

[t] Vent condenser.

[u] Vent scrubber.

[v]

[w]

[x]

[y] Mechanical refrigeration units and condensers.

[z] Refrigeration vapor recovery.

[aa] Nitrogen blankets and incineration.

[bb] Vapor recovery.

[cc] Conservation vents and inerts.

[dd] Refrigeration/recycle.

[ee] Compression and incineration.

[ff] Tank is nitrogen blanketed, submerged filled, insulated and refrigerated.

[gg]

TABLE 2-20. EDC EMISSIONS FROM PRESSURE VESSELS

Emission range, Mg/yr	No. of tanks	Total emissions, Mg/yr
0-1	7	0.13
1-5	3	10
>5	1	5.7
TOTAL	22	15.83

TABLE 2-21. PRESSURE VESSEL SUMMARY TABLE

No. of tanks	Emissions, Mg/yr[a]		Emission reduction, Mg/yr[a]		Cost effectiveness, $/Mg	
	EDC	VOC	EDC	VOC	EDC	VOC
1	5.7	11	5.4	10	5,350	720
2	3.5	3.5	3.3	3.3	600	600
1	3.0	6	2.7	5.5	690	180

[a] Per tank basis.

TABLE 2-22. COSTING DATA FOR CONTROL OF SHIPPING EMISSIONS First Quarter 1984 Dollars[a]

Plant/location	Shipping vehicle[b]	Current control technology[b]	Current control efficiency[b]	Current EDC emissions Mg/yr[b]	EDC emission reduction, Mg/yr[c]	Total capital cost,[d] $	Annualized cost,[d] $	EDC recovery credit,[e] $	Net annualized cost,[f] $	Cost effectiveness $/Mg[g]
Arco Chemicals, Port Arthur, Tex.	Barge	h	98	5.6	N/A[i]	N/A	N/A	N/A	N/A	N/A
B. F. Goodrich, Calvert City, Ky.	-------NO REPORTED SHIPPING OF EDC-------									
B. F. Goodrich, Convent, La.			N/R[k]	N/R	--[l]	--	--	--	--	--
B. F. Goodrich, LaPorte, Tex.			N/R	N/R	--	--	--	--	--	--
Borden, Geismar, La.	-------NO REPORTED SHIPPING OF EDC-------									
Diamond Shamrock, Deer Park, Tex.	-------NO REPORTED SHIPPING OF EDC-------									
Dow Chemical, NPA/EDC plant, Freeport, Tex.	--------NO AVAILABLE DATA-------									
Dow Chemical, 1,1,2 Trichloroethane plant Freeport, Tex.	-------NO REPORTED SHIPPING OF EDC-------									
Dow Chemical, Trichloro plant Freeport, Tex.	-------NO REPORTED SHIPPING OF EDC-------									
Dow Chemical, Oyster Creek, Tex.	-------NO REPORTED SHIPPING OF EDC-------									
Dow Chemical (Vinyl I), Plaquemine, La.	-------NO REPORTED SHIPPING OF EDC-------									
Dow Chemical (Vinyl II), Plaquemine, La.	-------NO REPORTED SHIPPING OF EDC-------									
Dow Chemical, Texas Division	-------NO REPORTED SHIPPING OF EDC-------									
E. I. duPont (Conoco), Westlake, La.				0 0	N/A N/A	N/A N/A	N/A N/A	N/A N/A	N/A N/A	N/A N/A
Ethyl Corporation, Baton Rouge, La.	Rail car	o	0	24	--	--	--	--	--	--
Formosa, Baton Rouge, La.	Barge	o	0	189	184	390,000	84,900	60,000	24,900	140
Formosa, Point Comfort, Tex.[p]	N/R	N/R	N/R	N/R	--	--	--	--	--	--
Georgia Pacific, Plaquemine, La.				N/R N/R N/R	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --

(continued)

TABLE 2-22. (continued)

Plant/Location	Shipping vehicle[b]	Current control tech-nology[b]	Current control effi-ciency[b]	Current EDC emis-sions Mg/yr[b]	EDC emission reduc-tion,[c] Mg/yr	Total capital[a] cost, $	Annual-ized[d] cost, $	EDC recovery[e] credit, $	Net annual-ized[f] cost, $	Cost effective-ness $/Mg[g]
Olin Corporation, Lake Charles, La.				N/R	N/A	N/A	N/A	N/A	N/A	N/A
PPG Industries, Lake Charles, La.[u]	Rail car Tank truck Barge	N/R	N/R	5						
Shell Chemical Co., Deer Park, Tex.	-------NO REPORTED SHIPPING OF EDC-------									
Union Carbide, Hahnville, La.	-------NO REPORTED SHIPPING OF EDC-------									
Vulcan Chemicals, Geismar, La.	Tank truck	v	N/R	0.50	--	--	--	--	--	--
	Rail car	v	N/R	1.6	--	--	--	--	--	--
	Barge	v	N/R	5.2	--	--	--	--	--	--
Vulcan Chemicals, Wichita, Kans.[w]	-------NO REPORTED SHIPPING OF EDC-------									

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[a] Calculated using CE Plant Cost Index and M&S Equipment Cost Index (Chemical Engineering, June 11, 1984).
[b] Cited from Section 114 information request.
[c] Efficiency of refrigeration system (98 percent) calculated by the differences in partial pressure per atmospheric pressure at: T_1 = standard temperature of storage vessel and T_2 = condensation.
[d] Reference No. 51.
[e] EDC value ~$326/Mg first quarter 1984 dollars, Reference No. 46.
[f] Annualized cost minus EDC recovery credits.
[g] Net annualized cost per unit of emissions reduced.
[h] Refrigerated vapor recovery system and incineration system.
[i] N/A = Not applicable. Already achieves 98 percent or greater control efficiency.
[j]
[k] N/R = Not reported.
[l] -- = Insufficient data upon which to base calculation.
[m]
[n]
[o] Submerged fill lines. Refrigerated vent condenser costed.
[p] All enclosed operation.
[q]
[r]
[s]
[t]
[u] Insufficient data provided for costing. Emissions cited are total for all three transportation modes.
[v] Vapor recovery (emissions noted are for drying and system maintenance).
[w] The 1983 emissions from loading grain fumigants are estimated at 67 kg/yr.

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3. PUBLICLY OWNED TREATMENT WORKS

3.1 ETHYLENE DICHLORIDE SOURCES AND EMISSIONS

In recent work sponsored by the EPA, POTW's were identified as sources of EDC emissions.[1] The premise of this work was that volatilization of EDC-bearing industrial discharges at the POTW, rather than secondary formation during wastewater treatment, is the most likely source of EDC emissions.[2] This work utilized existing data files to identify 1,600 POTW's (out of approximately 20,000 total nationwide) that treat industrial discharges.[3,4] Data available from these files (e.g., percent of inflow to POTW attributable to industrial dischargers, types of industries discharging to POTW, and type of treatment at POTW), along with a set of pollutant-specific emission factors for POTW's (available from mass-balance information for 50 POTW's), were used to estimate emissions of each of nine pollutants including EDC, from the 1,600 POTW's. The presence of these nine pollutants in the waste streams was presumed based on the Standard Industrial Classification Codes of the dischargers rather than on available sampling data from actual discharge streams. Three hundred fifty-five POTW's were projected to emit EDC.[1]

Table 3-1 presents a list of 95 counties containing POTW's having an estimated EDC emission level of at least 10 Mg/yr (11 tons/yr).[1] (Two hundred sixty additional counties were presented in Reference 1, each having EDC emissions less than 10 Mg/yr [11 tons/yr].) Total EDC emissions for all 355 POTW's are estimated to be approximately 7,300 Mg/yr (8,050 tons/yr).

Within a POTW, EDC in wastewater is volatilized to the atmosphere from the aeration basins or from the clarifiers. Any operation that generates aerosols (e.g., spray irrigation, trickling filters) or provides agitation of the wastewater (e.g., screens, grit chambers) could also enhance the release of EDC to the atmosphere.[1] No control measures specifically for VOC's or air toxics have been implemented.[1]

Recently, ambient air monitoring was performed in Philadelphia, Pennsylvania, to determine the validity of the emission estimates.[5] Ten monitoring stations were sited around Philadelphia, including the POTW, and samples were collected every third day for 3 months. The data from this sampling effort are being used to validate the ambient dispersion models used to relate pollutant emissions with influent wastewater concentrations. The air monitoring included analyses for EDC. The preliminary results of this testing approach indicate that the data developed using the approach cited in References 3 and 4 may overstate EDC emissions by a factor of eight to ten. A critical assessment of both sets of data (mass-balance and ambient monitoring) to determine which approach to estimating EDC emissions from POTW's is most accurate or whether the difference in the two approaches is likely to occur at other POTW's has not been made yet. Additional ambient monitoring may be performed in Baltimore, Maryland, to increase the amount of data available for validating the models.[5]

Since the primary emission point for EDC is the aeration basin, the most likely control strategy is pretreatment of the EDC-laden wastewater. Towards that end, effluent limitations guidelines for best practicable technology (BPT), best conventional technology (BCT), and best available technology (BAT), new source performance standards (NSPS), and pretreatment standards for the Organic Chemicals and Plastics and Synthetic Fibers Source Category will be promulgated in approximately 6 months.[2] These regulations will limit the discharge of effluents into receiving waters and into POTW's from facilities that produce organic chemicals, plastics, and synthetic fibers. Ethylene dichloride is one of the pollutants covered and will be regulated by the BAT, NSPS, pretreatment standards for existing sources of indirect discharges (PSES), and pretreatment standards for new sources of indirect discharges (PSNS).[5] (Indirect discharges are those to a POTW rather than directly to a receiving stream.) The selected technology for BAT, PSES, and PSNS is a combination of process controls, in-plant physical/chemical treatment, and end-of-pipe treatment (those processes that treat a combined plant stream prior to discharge). No individual or specific BAT is specified; because of the diversity of pollutants in the source category, BAT will be plant specific.[6] Existing technologies include biological treatment (preceeded by the necessary controls necessary to protect the biota), polishing ponds and filters, water reduction and reuse techniques, process changes, and product or solvent recovery (including distillation and steam stripping).

The effluent limitations for EDC are a 150 micrograms per liter ($\mu g/\ell$) maximum for any one day and a 100 $\mu g/\ell$ average of daily values for four consecutive monitoring days.[5] These limitation values are the same for BAT, NSPS, PSES, and PSNS sources. No estimate can be made of the impact of these effluent limitations on EDC air emissions from POTW's (or from the regulated sources). It is believed that the limitations will effectively remove EDC from the waste streams, and, thus, air emissions of EDC from POTW's should drop significantly.[2] The fate of the EDC removed from the waste stream at the plant is not addressed in the effluent limitations.

TABLE 3-1. ESTIMATED EDC EMISSIONS FROM PUBLICLY OWNED TREATMENT WORKS (By County)[1]

County	EDC emissions[a] Mg/yr	EDC emissions[a] Tons/yr
Ramsey, Minn.	782	862
Philadelphia, Pa.	760	837
Cook, Ill.	729	804
Middlesex, N.J.	498	549
Montgomery, Ohio	230	254
Dade, Fla.	224	247
Douglas, Nebr.	194	213
Union, N.J.	148	163
Harris, Tex.	148	163
St. Louis City, Mo.	138	153
Dane, Wis.	133	147
Sedgwick, Kans.	126	139
Tarrant, Tex.	123	135
Fulton, Ga.	121	134
Niagra, N.J.	92	101
San Francisco, Calif.	85	93
Orleans, La.	80	88
Broward, Fla.	76	84
Aiken, S.C.	76	84
Fairfield, Conn.	72	80
Lucas, Ohio	69	77
Baltimore City, Md.	68	75
Dallas, Tex.	60	66
Fort Bend, Tex.	60	66
Kittitas, Wash.	57	63
Lorain, Ohio	54	60
McLennan, Tex.	53	59
Tromboll, Ohio	52	57
Floyd, Ind.	47	52
Caddo, La.	46	50
Erie, N.Y.	43	47
Richmond, Ga.	41	45
Alameda, Calif.	38	42
Guilford, N.C.	38	41
Lenoir, N.C.	38	41

(continued)

TABLE 3-1. (continued)

County	EDC emissions[a]	
	Mg/yr	Tons/yr
Hamilton, Tenn.	36	39
Montgomery, N.Y.	32	36
Hampden, Mass.	32	35
Kalamazoo, Mich.	29	32
Essex, N.J.	29	32
Tulare, Calif.	27	30
Smith, Tex.	27	30
St. Clair, Ill.	27	29
Whitfield, Ga.	26	29
Madison, Tenn.	26	29
Johnson, Kans.	26	28
Miami, Ohio	25	27
Morgan, Ala.	23	25
Brown, Minn.	23	25
Twin Falls, Idaho	23	25
Story, Iowa	23	25
Alamance, N.C.	23	25
Worcester, Mass.	22	24
Hillsborough, N.H.	20	23
Cattaraucus, N.Y.	20	22
Santa Cruz, Calif.	20	22
Hamilton, Ohio	20	22
Monmouth, N.J.	20	22
Callaway, Mo.	19	21
Forsyth, N.C.	19	21
Durham, N.C.	18	20
Hudson, N.J.	17	19
Buncombe, N.C.	17	18
New Haven, Conn.	16	18
Burke, N.C.	15	17
Stanislaus, Calif.	15	17
Knox, Ind.	15	16
Cleveland, N.C.	15	16
Winnebago, Wis.	15	16
Kennebec, Maine	14	16

(continued)

TABLE 3-1. (continued)

County	EDC emissions[a]	
	Mg/yr	Tons/yr
Washington, Miss.	14	15
Angelina, Tex.	14	15
Jefferson, Tex.	14	15
Venango, Pa.	13	15
Ottawa, Mich.	13	15
Dodge, Wis.	13	15
Talladega, Ala.	13	14
Canyon, Idaho	12	14
Iredell, N.C.	12	13
Madison, Ala.	12	13
Hampshire, Mass.	12	13
Jackson, Ala.	12	13
Houston, Ala.	11	13
Washtenaw, Mich.	11	12
Morris, N.J.	11	12
Wayne, W. Va.	11	12
Lynchburg, Va.	11	12
Spartanburg, S.C.	11	12
Portsmouth, Va.	11	12
Oconee, S.C.	10	11
Cumberland, Pa.	10	11
York, S.C.	10	11
Columbiana, Ohio	10	11
Washington, Ark.	10	11
Boulder, Colo.	10	11
Total EDC emissions, top 95 counties	~6,660	~7,350
remaining 260 counties	~630	~690

[a] Estimated air emissions may be overstated by a factor of eight. See References 2 and 5.

3.2 REFERENCES

1. Memo and attachments from Lahre, T., EPA:AMTB, to Southerland, J. H., EPA:AMTB. December 5, 1983. Initial look at available emissions data on POTW's.

2. Telecon. Atkinson, D., MRI, with Haemisegger, E., EPA:OPA. August 28, 1984. Update on Versar POTW work.

3. Memo and attachment from Haemisegger, E., EPA:OPA, to Atkinson, R. D., MRI. August 31, 1984. Description of POTW emission estimation algorithm.

4. Memo and attachments from Alexandar, D., AMS, Inc., D. Sullivan and J. Alchowiak, Versar, Inc., to Haemisegger, E., and T. Gorman, EPA:OPA. February 7, 1984. Algorithm for estimating volatilization of air toxics from POTW's.

5. Telecon. Maxwell, W., MRI with Haemisegger, E., EPA:OPA. September 14, 1984. Additional information on EPA tests at Philadelphia.

6. U. S. Environmental Protection Agency. Proposed Effluent Guidelines Pretreatment Standards for Organic Chemicals, Plastics, and Synthetic Fibers Industry. 40 CFR Parts 414 and 416. Washington, D.C. Office of the Federal Register. March 21, 1983. Volume 48. pp. 11828+.

4. PHARMACEUTICAL MANUFACTURING PLANTS

4.1 ETHYLENE DICHLORIDE SOURCES AND EMISSIONS

Ethylene dichloride is one of many solvents used in the manufacture of synthetic pharmaceuticals. Pharmaceuticals are typically made in a series of batch operations, many of which involve the use of solvents. These operations include reactors, distillation systems, filters, extractors, centrifuges, crystallizers, dryers, and various holding tanks. Solvent emissions can occur in any of these process steps, and can also occur from solvent storage, transfer, and recovery systems. Solvents may be used as a reaction medium, to dissolve an intermediate product prior to a process step, to wash an intermediate or final product, or as a drier after a water-based production step.[1] No information was obtained on specific locations, applications, or emission points for EDC use in the pharmaceutical industry. The magnitude of gathering such information was beyond the scope of this study.

In May 1984, the Pharmaceutical Manufacturer's Association (PMA) solicited information from member companies on their use of four solvents, including EDC.[2] The EDC purchase, emission, and disposal statistics provided by the member companies are presented in Table 4-1. Responding companies account for about half of the 1982 domestic sales of prescription pharmaceuticals. However, the PMA indicated that some manufacturers may not have responded to the survey because they do not use any of the four solvents. Thus, the numbers may not accurately represent the actual ratio of EDC use to pharmaceutical sales and the doubling of the estimates in the responses (as is done in Table 4-1) may result in overestimation of true EDC purchase and losses for the entire industry.

From the table, it appears that as much as 800 Mg/yr (880 tons/yr) of EDC may be emitted directly from process operations or vessels with some possible indirect atmospheric losses from EDC disposal in sewers discharging to POTW's. (Some of these losses are no doubt included in the emission estimates for POTW's in Chapter 3.)

The summary of member company information that was provided to EPA did not include company- or plant-specific details on EDC emissions, only aggregate data. Similarly, no information was available as to the control practices (other than incineration) being used in the pharmaceutical manufacturing industry. Control techniques that could be investigated to control these emission sources include condensation, carbon adsorption, liquid scrubbing, incineration, vapor balance systems, pressurized tanks, internal floating roof tanks, and inspection and maintenance programs. The control techniques are similar to those in chemical plants discussed in Chapter 2, although the batch nature of pharmaceutical manufacturing often produces intermittent and variable emissions that can be expensive to control per unit of EDC removed. To estimate the costs of controls and emission reductions achievable, a specific study on this industry will be necessary.

TABLE 4-1. SUMMARY OF ESTIMATED EDC USE AND EMISSIONS IN THE PHARMACEUTICAL MANUFACTURING INDUSTRY[2]

	Actual data from member companies, Mg/yr	Industry-wide totals,[a] Mg/yr
Annual EDC purchased[b]	1,400	2,800
Direct EDC air emissions	400	800
EDC discharged to sewer	250	500
EDC incinerated	775	1,550

[a] Data shown are twice those reported by pharmaceutical firms representing approximately one-half of the 1982 domestic sales of prescription pharmaceuticals. Values shown may be overstated because those companies not responding to the survey may not use EDC.

[b] Note that amount purchased does not represent amount used but amount purchased to replace losses. Amount used not reported by Reference 2.

4.2 REFERENCES

1. U. S. Environmental Protection Agency. Control of Volatile Organic Emissions from Manufacture of Synthesized Pharmaceutical Products. Research Triangle Park, North Carolina. Publication No. EPA-450/2-78-029. December 1978.

2. Letter and enclosure from White, T. X., Pharmaceutical Manufacturers Association, to Beck, D. A., EPA:ESED. June 8, 1984. Information on solvent use by pharmaceutical plants.

5. LEAD SCAVENGER BLENDING FACILITIES

5.1 ETHYLENE DICHLORIDE USE AND EMISSIONS

Ethylene dichloride is blended with chemicals, such as ethylene dibromide (1,2-dibromoethane, EDB), to form lead scavenger additives for use in leaded gasoline.[1],[2] Typical concentrations for EDC in leaded gasoline are 150 to 300 ppm.[3] The addition of these compounds prevents the fouling of the engine combustion chamber with lead oxides. Ethylene dichloride and EDB react with lead during combustion to form lead chloride ($PbCl_2$) and lead bromide ($PbBr_2$) which remain in the gas phase and are expelled with the exhaust gases.

About 0.3 percent (20,000 Mg [22,500 tons]) of the EDC produced in 1983 was used as a lead scavenger. Table 5-1 lists the four plants that produce lead scavenger additives.

Because the use of leaded gasoline has been decreasing since the introduction of catalytic control devices on automobiles in the early 1970's, and is expected to continue to decline as noncatalyst vehicles are retired from the fleet, emissions of EDC from the production and use of lead scavenger additives are also expected to decline. Also, a recent EPA proposal to reduce the lead content in gasoline by 91 percent by 1986 would hasten the decline of EDC emissions from this source.[4] The EPA is also considering a total ban of leaded gasoline by 1995.[4]

Potential sources of emissions during manufacture of the additive are similar to those at a chemical plant, i.e., process, fugitive, secondary, and storage. Process sources differ the most because the lead scavenger production process involves blending of several compounds rather than a chemical synthesis. Thus, in lead scavenger production, EDC does not undergo a chemical change to other compounds. The blending process is therefore typically conducted under atmospheric conditions, compared to the elevated pressures and temperatures often used in chemical synthesis.

Tables 5-2 through 5-9 list these EDC and VOC emission sources for specific plants, and give their respective control practices, emission rates, and estimates of the costs of additional controls. The same additional controls and the criteria for determining their applicability for each source type were used here as were discussed in Chapter 2. These additional controls were incinerators on process vent emissions; a combination of equipment control devices and inspection and maintenance programs for fugitive emissions; and floating roof tanks for storage emissions. The emission reduction potential and costs of applying a refrigerated vent condenser on one process vent were calculated. Incineration was not applicable in this instance because some emissions occur during nonoperating hours, when personnel would not be available to operate the incinerator. Vent condensers, by contrast, could operate safely without continuous monitoring.

Approximately 76 Mg/yr (84 tons/yr) of EDC are emitted from three of the four plants listed in Table 5-1. Emissions from the fourth plant, Ethyl Corporation in Baton Rouge, Louisiana, were discussed in Chapter 2 because this facility produces EDC on site. No other lead additive manufacturers reported manufacturing their own EDC. Approximately 195 Mg/yr (215 tons/yr) of VOC are emitted from these three plants.

Table 5-10 summarizes the potential EDC emission reduction data from each plant by source. Process vents are the largest source of EDC emissions, responsible for approximately 55 percent of current emissions; followed by storage, 28 percent; fugitive, 14 percent; and secondary, 3 percent. These companies reported no shipping of EDC; consequently, there are no shipping emissions.

By applying the above control techniques, EDC emissions from lead additive production could be reduced by approximately 69 Mg/yr (76 tons/yr), a 91 percent reduction. However, most of this emission reduction potential would be achieved at a cost effectiveness that is relatively high compared to that achievable by chemical plants (discussed in Chapter 2). The cost effectiveness of further controlling process vent emissions ranges from $9,600 to $427,600/Mg ($8,700 to $387,800/ton), with an overall cost effectiveness of $17,300/Mg ($15,700/ton). The cost effectiveness of fugitive emission controls ranges from $660 to $44,100/Mg ($600 to $40,000/ton), and averages approximately $900/Mg ($820/ton). Storage emissions can be controlled by floating roof tanks with primary seals only for $5,800 to $10,800/Mg ($5,300 to $9,800/ton), and an average of $9,200/Mg ($8,300/ton). Sample cost calculations are given in Appendix A.

Sources of EDC emissions from transportation and use of leaded gasoline include blending operations at refineries, bulk gasoline marketing and transportation, service stations, gasoline combustion, and evaporation from the vehicles. In a separate study, EPA estimated EDC emissions from gasoline marketing sources (i.e., bulk terminals, bulk plants, and service stations) to be about 245 Mg/yr (270 tons/yr) in 1982.[5] This emission level will decline over the years as a result of lead phase-down. An analysis of the effects of various control scenarios on EDC emissions from gasoline marketing is presented in the EPA document referenced above. Emissions were not estimated within the scope of this study for gasoline combustion and evaporation from vehicles, although emission levels are expected to be very low.

TABLE 5-1. PRODUCERS OF LEAD SCAVENGER ADDITIVE

Company	Location
E. I. duPont	Antioch, California Deepwater, New Jersey
Ethyl Corporation	Baton Rouge, Louisiana
Nalco Chemicals	Freeport, Tex.

TABLE 5-2. EMISSION AND CONTROL COST DATA FOR PROCESS EMISSIONS 1984 Dollars[a]

Plant/location, Process source[b]	Current control technology[b]	Current control efficiency, %[b]		Current EDC/VOC emissions, Mg/yr[b]	Additional controls	EDC/VOC emission reduction, Mg/yr	Capital cost, $	Net annual cost, $	Cost effectiveness[c]	
		EDC	VOC						EDC emission reduction, $/Mg	VOC emission reduction, $/Mg
E. I. duPont Antioch, Calif.										
(a) Blender during operation	d	98[e]	98[e]	0.10/0.2	N/A[f]	N/A	N/A	N/A	N/A	N/A
(b) Blender when not operating	g	0	0	0.80/2.12	Refrigerated vent condenser[h]	0.76/1.25[h]	858,000[h]	201,400[h]	265,000[h]	161,000[h]
E. I. duPont Deep Water, N.J.										
(a) MFAC blending	i	19	32	41/60	Incinerator[j]	40/58.6[j]	1,211,000[j]	382,000[j]	9,600[j]	6,400[j]
Nalco Chemical Freeport, Tex.										
(a) Common flare stack	k	98	98	0.02/1.02	N/A	N/A	N/A	N/A	N/A	N/A

[a] Calculated using CE Plant Cost Index (Chemical Engineering, June 11, 1984).
[b] Cited from information request.
[c] Annualized cost per unit of emission reduced.
[d] Incinerator.
[e] Actual emission efficiency reported as >98 percent; however, insufficient data were available to verify this efficiency.
[f] N/A = Not applicable. No additional controls costed if efficiency already ≥98 percent.
[g] No control device used when blender is not operating. See text for additional explanation.
[h] The emission reduction potential and costs of installing a 95 percent efficient refrigerated vent condenser when the blender is not operating were calculated. The condenser system costed was a shell-and-tube type with a storage tank, a pump and the necessary piping and instruments. The refrigeration unit included the compressor, condenser expansion valve, evaporator, controls, foundations and all auxiliary components. Sample cost calculations appear in Appendix A. Methodology from Reference 6.
[i] Vapor return within vessels for motor fuel antiknock compound (MFAC) blending.
[j] The emission reduction potential and costs of installing a 98 percent efficient incinerator were calculated. Sample costs calculations appears in Appendix A. Methodology from Reference 7.
[k] Knock-out pot, flare gas absorber.

TABLE 5-3. EDC EMISSIONS AND COST DATA FOR RETROFITTING FIXED ROOF STORAGE TANKS WITH INTERNAL FLOATING ROOFS (Primary Seals)

March 1984 Dollars[a]

Plant/Location	Tank type[b,c]	Percent EDC stored	No. of storage tanks	Current control techniques[b]	Current control efficiency[b]	Current EDC emissions Mg/yr[d]	Total capital cost, $[e,f]	Annualized cost,[g] $	EDC emission Mg/yr reduction[h]	EDC recovery credits $[a,i]	Net annualized costs,[j] $	Cost effectiveness $/Mg[k]
E. I. duPont Antioch, Calif.	F	100	1	l	0	1.1	23,000	6,100	1.0	340	5,800	5,800
E. I. duPont Deep Water, N.J.	F	11-25	8	m	50-80	0.95	37,900	10,000	0.90	290	9,700	10,800
	HP	99	1	n	100	0	N/A[o]	N/A	N/A	N/A	N/A	N/A
	F	11-25	5	m	50-80	0.95	33,300	8,800	0.90	280	8,400	9,300
	F	11-25	2	m	50-80	0.85	33,100	8,700	0.80	260	8,400	10,500
	F	11-25	3	m	50-80	1.9	52,500	13,800	1.80	570	13,200	7,300
Nalco Chemical Freeport, Tex.	F (PV)	19	3	p	96	0.03	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	19	1	p	96	0.03	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	19	2	p	96	0.03	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	19	1	p	96	0.01	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	100	1	p	96	0.06	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	10	1	p	96	0.01	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	19	5	p	96	0.01	N/A	N/A	N/A	N/A	N/A	N/A

[a] Calculated using CE Plant Cost Index and M&S Equipment Cost Index (Chemical Engineering June 11, 1984).

[b] Cited from information request responses.

[c] Tank types.

F = Fixed roof.
CIF = Contact internal floating roof.
S = Spherical tank.
H = Horizontal tank.
HP = Horizontal pressure tank.
PV = Pressure vessel.

[d] Current storage tank emissions (per tank basis) based upon information request responses.

[e] Refer to Table 2-13.

[f] Additional cost for the use of a Teflon® coated primary seal ~\$230/m (m = meter of diameter), Reference No. 8.

[g] Reference No. 9.

[h] Internal floating roof (primary seal only), 94 percent emission reduction efficiency.

[i] EDC value ~\$326/Mg (First Quarter 1984 dollars), Reference No. 10.

[j] Annualized cost minus EDC recovery credits.

[k] Net annualized cost per unit of emissions reduced.

[l] None.

[m] Floating liquid barrier.

[n] Vapor transfer when unloading tank cars and conservation vent.

[o] N/A = Not applicable. No additional controls costed if efficiency already ≥94 percent.

[p] Nitrogen pad system maintained at 1.5 psig. The system is put through a flare gas absorber tower, followed by a flare knock-out drum before being routed to a flare.

TABLE 5-4. VOC EMISSIONS AND COST DATA FOR RETROFITTING FIXED ROOF STORAGE TANKS WITH INTERNAL FLOATING ROOFS (Primary Seals)

March 1984 Dollars[a]

	Tank type[b,c]	No. of storage tanks	Current control techniques[b]	Current control efficiency[b]	Current VOC emissions, Mg/yr[d]	Total capital cost, $[e,f]	Annualized cost,[g] $	VOC emission Mg/yr reduction[h]	VOC recovery credits, $[i,j]	Net annualized costs,[k] $	Cost effectiveness $/Mg[l]
E. I. duPont Antioch, Calif.	F	1	m	0	1.1	23,000	6,100	1	330	5,800	5,800
E. I. duPont Deep Water, N.J.	F	8	n	50-80	3.8	37,900	10,000	3.5	1,150	8,850	2,500
	HP	1	o	100	0	N/A	N/A	N/A	N/A	N/A	N/A
	F	5	n	50-80	3.7	33,300	8,800	3.5	1,150	7,700	2,200
	F	2	n	50-80	3.4	33,100	8,700	3.1	1,000	7,700	2,500
	F	3	n	50-80	7.6	52,500	13,800	7	2,300	11,500	1,650
Nalco Chemical Freeport, Tex.	F (PV)	3	p	96	0.16	N/A[q]	N/A	N/A	N/A	N/A	N/A
	F (PV)	1	p	96	0.16	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	2	p	96	0.16	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	1	p	96	0.05	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	1	p	96	0.06	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	1	p	96	0.10	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	5	p	96	0.05	N/A	N/A	N/A	N/A	N/A	N/A

[a] Calculated using CE Plant Cost Index and M&S Equipment Cost Index (Chemical Engineering June 11, 1984).

[b] Cited from information request responses.

[c] Tank types.
  F = Fixed roof.
  CIF = Contact internal floating roof.
  S = Spherical tank.
  H = Horizontal tank.
  HP = Horizontal pressure tank.
  PV = Pressure vessel.

[d] Current storage tank emissions (per tank basis) based upon information request responses.

[e] Refer to Table 2-13.

[f] Additional cost for the use of a Teflon® coated primary seal ~$230/m (m = meter of diameter), Reference No. 8.

[g] Reference No. 9.

[h] Internal floating roof (primary seal only), 94 percent emission reduction efficiency.

[i] EDC value ~$326/Mg (First Quarter 1984 dollars), Reference No. 10.

[j] Assumed VOC value equal to EDC value.

[k] Annualized cost minus EDC recovery credits.

[l] Net annualized cost per unit of emissions reduced.

[m] None.

[n] Floating liquid barrier.

[o] Vapor transfer when unloading tank cars and conservation vents.

[p] Nitrogen pad system maintained at 1.5 psig. The system is put through a flare gas absorber tower, followed by a flare knock-out drum before being routed to a flare.

[q] N/A = Not applicable. No additional controls costed if existing efficiency ≥94 percent.

TABLE 5-5. EDC EMISSIONS AND COST DATA FOR RETROFITTING FIXED ROOF STORAGE TANKS WITH INTERNAL FLOATING ROOFS (Primary and Secondary Seals) March 1984 Dollars[a]

Plant/Location	Tank type[b,c]	Percent EDC stored	No. of storage tanks	Current control techniques[b]	Current control efficiency[b]	Current EDC emissions Mg/yr[d]	Total capital cost, $[e,f,g]	Annualized cost,[h] $	EDC emission Mg/yr reduction[i]	EDC recovery credits $[a,j]	Net annualized costs,[k] $	Cost effectiveness $/Mg[l]
E. I. duPont Antioch, Calif.	F	100	1	m	0	1.1	27,000	7,100	1.1	360	6,700	6,100
E. I. duPont Deep Water, N.J.	F	11-25	8	n	50-80	0.95	44,900	11,800	0.92	300	11,500	12,500
	HP	99	1	o	100	0	N/A[p]	N/A	N/A	N/A	N/A	N/A
	F	11-25	5	n	50-80	0.95	39,300	10,300	0.92	300	10,000	10,100
	F	11-25	2	n	50-80	0.85	39,100	10,300	0.82	270	10,000	12,200
	F	11-25	3	n	50-80	1.9	62,500	16,400	1.8	600	15,800	8,800
Nalco Chemical Freeport, Tex.	F (PV)	19	3	q	96	0.03	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	19	1	q	96	0.03	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	19	2	q	96	0.03	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	19	1	q	96	0.01	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	100	1	q	96	0.06	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	10	1	q	96	0.01	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	19	5	q	96	0.01	N/A	N/A	N/A	N/A	N/A	N/A

[a] Calculated using CE Plant Cost Index and M&S Equipment Cost Index (Chemical Engineering June 11, 1984).

[b] Cited from information request responses.

[c] Tank types.

F = Fixed roof.
CIF = Contact internal floating roof.
S = Spherical tank.
H = Horizontal tank.
HP = Horizontal pressure tank.
PV = Pressure vessel.

[d] Current storage tank emissions (per tank basis) based upon information request responses.

[e] Refer to Table 2-13.

[f] Additional cost for the use of a Teflon® coated primary seal ~$230/m (m = meter of diameter), Reference No. 8.

[g] Cost for a Viton® coated secondary seal ~656/m (m = meters of diameter) 1st Quarter 1984 dollars, Reference No. 11.

[h] Reference No. 9.

[i] Internal floating roof (primary and secondary seal), 97 percent emission reduction efficiency.

[j] EDC value ~$326/Mg (First Quarter 1984 dollars), Reference No. 10.

[k] Annualized cost minus EDC recovery credits.

[l] Net annualized cost per unit of emissions reduced.

[m] None.

[n] Floating liquid barrier.

[o] Vapor transfer when unloading tank cars and conservation vent.

[p] N/A = Not applicable.

[q] Nitrogen pad system maintained at 1.5 psig. The system is put through a flare gas absorber tower, followed by a flare knock-out drum before being routed to a flare.

TABLE 5-6. VOC EMISSIONS AND COST DATA FOR RETROFITTING FIXED ROOF STORAGE TANKS WITH INTERNAL FLOATING ROOFS (Primary and Secondary Seals)

March 1984 Dollars[a]

	Tank type[b,c]	No. of storage tanks[b]	Current control techniques	Current control efficiency	Current VOC emissions, Mg/yr[d]	Total capital cost, $[e,f,g]	Annualized cost,[h] $	VOC emission Mg/yr reduction[i]	VOC recovery credits, $[j,k]	Net annualized costs,[l] $	Cost effectiveness $/Mg[m]
E. I. duPont Antioch, Calif.	F	1	n	0	1.1	27,000	7,100	1.1	360	6,700	6,100
E. I. duPont Deep Water, N.J.	F	8	o	50-80	3.8	44,900	11,800	3.7	1,200	10,600	2,900
	HP	1	p	100	0	N/A[q]	N/A	N/A	N/A	N/A	N/A
	F	5	o	50-80	3.7	39,300	10,300	3.6	1,200	9,100	2,500
	F	2	o	50-80	3.4	39,100	10,300	3.3	1,100	9,200	2,800
	F	3	o	50-80	7.6	62,500	16,400	7.4	2,400	14,000	1,900
Nalco Chemical Freeport, Tex.	F (PV)	3	r	96	0.16	N/A[r]	N/A	N/A	N/A	N/A	N/A
	F (PV)	1	r	96	0.16	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	2	r	96	0.16	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	1	r	96	0.05	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	1	r	96	0.06	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	1	r	96	0.10	N/A	N/A	N/A	N/A	N/A	N/A
	F (PV)	5	r	96	0.05	N/A	N/A	N/A	N/A	N/A	N/A

[a] Calculated using CE Plant Cost Index and M&S Equipment Cost Index (Chemical Engineering June 11, 1984).

[b] Cited from information request responses.

[c] Tank types.

F = Fixed roof.
CIF = Contact internal floating roof.
S = Spherical tank.
H = Horizontal tank.
HP = Horizontal pressure tank.
PV = Pressure vessel.

[d] Current storage tank emissions (per tank basis) based upon information request responses.

[e] Refer to Table 2-13.

[f] Additional cost for the use of a Teflon® coated primary seal ~$230/m (m = meter of diameter), Reference No. 8.

[g] Cost for a Viton® coated secondary seal ~656/m (m = meters of diameter) 1st Quarter 1984 dollars, Reference No. 11.

[h] Reference No. 9.

[i] Internal floating roof (primary and secondary seal), 97 percent emission reduction efficiency.

[j] Assumed VOC value equal to EDC value.

[k] EDC value ~$326/Mg (First Quarter 1984 dollars), Reference No. 10.

[l] Annualized cost minus EDC recovery credits.

[m] Net annualized cost per unit of emissions reduced.

[n] None.

[o] Floating liquid barrier.

[p] Vapor transfer when unloading tank cars and conservation vent.

[q] N/A = Not applicable.

[r] Nitrogen pad system maintained at 1.5 psig. The system is put through a flare gas absorber tower, followed by a flare knock-out drum before being routed to a flare.

TABLE 5-7. COSTS FOR IMPLEMENTATION OF CONTROL TECHNIQUES FOR EDC FUGITIVE EMISSION SOURCES First Quarter 1984 Dollars[a]

Plant/Location	Current control techniques[b,c]	Current control efficiency %[b]	Current EDC emissions, Mg/yr[b]	Additional EDC emission reduction, Mg/yr[d]	Total capital cost, $[d]	Annualized cost, $[d]	EDC recovery credit, $[d,e]	Net annualized cost[f]	Cost effectiveness, $/Mg EDC[g]
E. I. duPont Deep Water, N.J.	h	60	1.5	0.9	3,400	2,300	300	2,000	2,200
E. I. duPont Antioch, Calif.	N/A	N/A	0.024	0.016	1,300	710	5	705	44,100
Nalco Chemical Freeport, Tex.	N/A	N/A	9	8	18,200	7,900	2,600	5,300	660

[a] Calculated using CE Plant Cost Index and M&S Equipment Cost Index (Chemical Engineering June 11, 1984).

[b] Information sited from information request responses.

[c] Current control techniques were not listed if the technique or technology was judged to have 0 percent control efficiency.

[d] Based upon proposed emission control techniques and control efficiencies listed in Table 2-8.

[e] EDC valve ~$326/Mg First Quarter 1984 dollars, Reference No. 10.

[f] Annualized cost minus recovery credit.

[g] Net annualized cost per unit of emissions reduced.

[h] Pressure relief devices protected by rupture disc (100 percent efficiency)

TABLE 5-8. COSTS FOR IMPLEMENTATION OF CONTROL TECHNIQUES[a] FOR VOC FUGITIVE EMISSION SOURCES First Quarter 1984 Dollars[a]

Plant/Location	Current control techniques[b,c]	Current control efficiency %[b]	Current VOC emissions, Mg/yr[b]	Additional VOC emission reduction, Mg/yr[d]	Total capital cost, $[d]	Annualized cost, $[d]	VOC recovery credit, $[a,e,f]	Net annualized cost[g]	Cost effectiveness, $/Mg VOC[h]
E. I. duPont Deep Water, N.J.	i	60	6	4	3,400	2,300	1,300	1,000	250
E. I. duPont Antioch, Calif.	N/A	N/A	2	2	1,300	710	650	60	30
Nalco Chemical Freeport, Tex.	N/A	N/A	40	37	18,200	7,900	12,100	-4,200	-110

[a] Calculated using CE Plant Cost Index and M&S Equipment Cost Index (Chemical Engineering June 11, 1984).

[b] Information sited from information request responses.

[c] Current control techniques were not listed if the technique or technology was judged to have 0 percent control efficiency.

[d] Based upon proposed emission control techniques and control efficiencies listed in Table 2-8.

[e] EDC valve ~$326/Mg First Quarter 1984 dollars, Reference No. 10.

[f] Assumed VOC value = EDC value.

[g] Annualized cost minus recovery credit.

[h] Net annualized cost per unit of emissions reduced.

[i] Pressure relief valves protected by rupture discs (100 percent efficiency).

TABLE 5-9. SECONDARY EDC EMISSION SOURCES

Plant/ Plant location/ Emission source	Current emissions, Mg/yr	Existing control technology	Applicable additional control technology	Capital and annual cost for additional control, $	Cost effectiveness additional control
E. I. duPont Antioch, Calif.	0.007	a	None	--[b]	--
E. I. duPont Deep Water N.J.	2.4	c	None	--	--
Nalco Chemical Freeport, Tex.	0.05	c	None	--	--

[a] Airstripping, settling, neutralization.

[b] -- = No additional controls costed.

[c] Wastewater to discharge or to primary and secondary treatment is pretreated by steam stripping to remove EDC. EDC is removed and recycled.

TABLE 5-10. EDC EMISSION SUMMARY

Plant/location	Process	Storage	Fugitive	Secondary	Shipping	Total
E. I. duPont, Antioch, Calif.						
Current emissions, Mg/yr	0.9	1.1	1.5	0.007	N/A[a]	3.5
Reduction potential, Mg/yr	0.76	1.0	0.9	N/A[b]	N/A[a]	2.7
E. I. duPont, Deep Water, N.J.						
Current emissions, Mg/yr	41	19.75	0.024	2.4	N/A[a]	63.2
Reduction potential, Mg/yr	40	18.7	0.016	N/A[b]	N/A[a]	58.7
Nalco Chemical, Freeport, Tex.						
Current emissions, Mg/yr	0.02	0.27	9	0.05	N/A[a]	9.3
Reduction potential, Mg/yr	N/A[c]	N/A[d]	8	N/A[b]	N/A[a]	8
Totals						
Current emissions, Mg/yr	42.0	21.1	10.5	2.5	N/A[a]	76.0
Reduction potential, Mg/yr	40.8	19.7	8.9	N/A[b]	N/A[a]	69.4

[a] Company reported no shipping of EDC.

[b] Insufficient data reported to determine feasibility of applying steam stripping, as discussed in Chapter 2.

[c] No additional process controls costed if existing controls ≥98 percent.

[d] No additional storage controls costed if existing controls ≥94 percent.

5.2 REFERENCES FOR CHAPTER 5

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6. MISCELLANEOUS USES AND EMISSION SOURCES

6.1 ETHYLENE DICHLORIDE SOURCES AND EMISSIONS

Minor uses of EDC are in textile cleaning and processing, in coatings, in formulations of acrylic-type adhesives, as a product intermediate for polysulfide elastomers, as a constituent of polysulfide rubber cements, in the manufacture of grain fumigants, and as a cleaning and extraction solvent.[1] These minor uses accounted for only 0.1 percent of the EDC produced in 1983. Of the estimated consumption of EDC by minor uses, about 28 percent is used in the manufacture of paints, coatings, and adhesives. Extracting oil from seeds, treating animal fats, and processing pharmaceutical products (discussed in Chapter 4) account for 23 percent. An additional 19 percent is consumed in cleaning textile products and PVC manufacturing equipment. Nearly 11 percent is used in the preparation of polysulfide compounds. Grain fumigation requires about 10 percent. The remaining 9 percent is used as a carrier for amines in leaching copper ores, in the manufacture of color film, as a diluent for pesticides and herbicides, and for other miscellaneous purposes.[2] Some of these uses are discussed below.

Estimates of EDC emissions from the miscellaneous uses are provided where possible. No information was obtained on specific emission points for EDC. The magnitude of gathering such information was beyond the scope of this study. To estimate the cost of controls and emission reductions achievable, specific study of these industries will be necessary.

6.1.1 Paints, Coatings, and Adhesives

A study performed by the EPA's Office of Air Quality Planning and Standards estimated that about 1,400 Mg of EDC per year (1,540 tons/yr) are used in the manufacture of paints, coatings, and adhesives.[3] Although specific uses of EDC in paints and coatings are not known, EDC is thought to be used as a solvent in paints and coatings which use vinyl polymers, particularly PVC. Ethylene dichloride use in adhesives is restricted to adhesives using acrylics.[4]

Because EDC is used as a solvent in paints, coatings, and adhesives, it is estimated that all of the EDC used in these products is eventually emitted to the atmosphere.[4] Data are not available on the relative amounts of EDC emitted during formulation and use of these products.

6.1.2 Extraction Solvent

Ethylene dichloride is used in a number of solvent extraction applications. Major applications include the extraction of oil from seeds, the processing of animal fats, and the processing of pharmaceutical products. Another EPA study estimated that EDC use as an extraction solvent accounts for about 1,100 Mg/yr (1,200 tons/yr).[5]

The solvent used in extraction processes is generally recovered by low pressure distillation. Some solvent is lost to the atmosphere from valves, pumps, and compressors; in spills; and during transfer operations. It is estimated in published literature that about 95 percent of the EDC consumed in solvent extraction processes is emitted to the atmosphere, while about 5 percent is discharged with solid wastes. These solid wastes are generally incinerated.[5] Therefore, about 1,050 Mg/yr (1,150 tons/yr) of EDC are emitted to the air from extraction processes.

6.1.3 Cleaning Solvent

Solvents containing EDC are used in cleaning equipment in the PVC and textile manufacturing industries. It is estimated that this use accounts for about 910 Mg/yr (1,000 tons/yr).[6] Data are not available on the equipment cleaned, the specific nature of the cleaning operations, or the compositions of the solvents used.

Although no emissions data are available for solvent cleaning uses of EDC, it is estimated in the literature that about 95 percent (or 860 Mg/yr [950 tons/yr]) of the EDC consumed is ultimately emitted to the atmosphere, while the remaining 5 percent is discharged with solid wastes.[6] These solid wastes are generally incinerated.

6.1.4 Polysulfide Rubber Production

Polysulfide rubber is a synthetic rubber polymer which is used in the manufacture of caulking putties, cements, sealants, and rocket-fuel. It is produced by the reaction between aliphatic halides, such as EDC, and alkali polysulfides such as Na_2S_4. The main products of the reaction are the polysulfide rubber chain, $(CH_2CH_2\text{-}S_4)_n$, and sodium chloride.[7]

Based on yields for similar industrial chemical reactions, the second EPA study estimated that 94 percent of the EDC used during the manufacturing of polysulfide rubber becomes incorporated in the end product.[7] It is estimated that 5 percent of the EDC used in the process is released to the atmosphere via leaks, spills, and fugitive emissions associated with the overall polysulfide manufacturing process. The remaining 1 percent of EDC remains dissolved in the mother liquor from which the polymer is produced. The mother liquor may be discharged as solid waste and stored in landfills.[7]

From the stoichiometry of the polysulfide production reaction and the percentages of EDC consumed and emitted, the average controlled EDC emission factor for polysulfide rubber manufacture is 33.8 kg of EDC per Mg of polysulfide rubber produced (67.6 lb/ton).[7] Only one company was reported to be manufacturing polysulfide rubber in 1983, and no production figures were reported by the EPA study, so no EDC emission estimate can be made.[7]

6.1.5 Grain Fumigant

Ethylene dichloride is used as a component of fumigant mixtures that are applied to control insect infestations in grains during storage, transfer, milling, distribution, and processing. Ethylene dichloride comprises 7.1 percent of the total weight of fumigant active ingredients applied to stored grain. Annual usage of EDC in grain fumigants ranged from 870 to 1,570 Mg/yr (960 to 1,730 tons/yr) during the period from 1976 to 1979.[8]

Due to its flammability, EDC is used in fumigant mixtures with carbon tetrachloride, which decreases the fire and/or explosion hazard of the mixture. A product containing three parts EDC to one part carbon tetrachloride (3:1) has been used widely. Other grain fumigant formulations have EDC:carbon tetrachloride ratios ranging from 2.4:1 to 1:7.

Other constituents may be present in these formulations, including EDB and carbon disulfide.[8]

Liquid grain fumigants are used on approximately 12 percent of the grain grown in the United States.[9] Fumigants are used during binning (placement in storage) and turning (shifting from one storage facility to another) operations or at any time during storage when infestation occurs. Fumigants have a period of effectiveness of only a few days. Thus, they kill existing insect populations but do not prevent later reinfestation. Newly harvested grain typically is fumigated 6 weeks after binning. Corn grown in the southern regions of the U.S. usually is fumigated immediately following binning because of field infestation of weevils.[10]

Emissions of EDC from fumigant mixtures occur during fumigant application and when fumigated grain is exposed to the atmosphere, for instance, during turning or loading. The rate of emissions of EDC from fumigant use depends on a number of factors including the type of grain, the type and concentration of fumigant applied, the type of storage (whether loose or tight-fitting), the manner in which the grain is handled, and the rate of release of fumigant residues in and on the grain.[11] Although high sorption efficiencies (84 percent) have been reported for certain cereals, it is generally concluded that by the time the grain is processed, essentially all of the retained EDC will have been dissipated to the atmosphere.[12] Thus, up to 1,500 Mg/yr (1,650 tons/yr) of EDC may be emitted to the atmosphere from grain fumigation.

6.1.6 Liquid Pesticide Formulations

Ethylene dichloride is used in a number of liquid pesticide formulations. These formulations generally are mixtures of EDC and other active ingredients such as carbon tetrachloride and carbon disulfide.[8]

Pesticide formulation systems are typically batch mixing operations. Technical grade pesticide is usually stored in its original shipping container in the warehouse section of the plant until it is needed. If the material is received in bulk, it is transferred to holding tanks for storage. Solvents are normally stored in bulk tanks.

Batch mixing tanks are typically closed vessels. The components of the formulation are fed into the tank, measured by weight, and mixed by circulation with a tank pump.[13] The formulated material is then pumped to a holding tank before being put into containers for shipment.

The blend tank is vented to the atmosphere through a vent dryer, which prevents moisture from entering the tank.[13] Storage and holding tanks and container-filling lines may be provided with an exhaust connection or hood to remove any vapors. The exhaust from the system may be vented to a control device or directly to the atmosphere.[14]

Sources of EDC emissions from pesticide formulation include storage vessels, mixing vessel vents, and leaks from pumps, valves, and flanges. Insufficient information is available for the development of EDC emission factors for liquid pesticide formulation facilities. No national emission estimates for EDC from liquid pesticide formulation are available.

6.1.7 Miscellaneous EDC Uses

Ethylene dichloride is used in the manufacture of color film, as a diluent in pesticides and herbicides, and as an amine carrier in the leaching of copper ores. The total amount of EDC used in these applications is 460 Mg/yr (500 tons/yr).[15] Very little information is available in published sources regarding the details of these processes.

It is estimated in published literature that all of the EDC used in the manufacture of pesticides, herbicides, and color film is emitted to the atmosphere, while nearly all of the EDC used in copper leaching is either consumed in the leaching process or emitted with wastewater.[15]

6.1.8 Volatilization From Waste Treatment, Storage, and Disposal Facilities

Considerable potential exists for volatile substances, including EDC, to be emitted from hazardous waste treatment, storage, and handling facilities. A study in California shows that significant quantities of EDC may be contained in hazardous wastes, which may be expected to volatilize within hours, days, or months after disposal by landspreading, surface impoundment, or covered landfill, respectively.[16] Volatilization of EDC and other substances was confirmed in this study by significant ambient air concentrations of EDC over one site. Reference 17 provides general theoretical models for estimating volatile substance emissions from a number of generic kinds of waste handling operations, including surface impoundments, landfills, landfarming (land treatment) operations, wastewater treatment systems, and drum storage/handling processes. If such a facility is known to handle EDC, the potential should be considered for some air emissions to occur.

6.2 REFERENCES

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APPENDIX A

SAMPLE CALCULATIONS FOR CONTROL COSTS AND COST EFFECTIVENESS

SECTION A-1: SAMPLE CALCULATIONS FOR FUGITIVE COSTS

To calculate the cost for the implementation of technologies to control fugitive emissions, the specific control techniques, removal efficiencies and capital/annualized costs per component are given in Table A-1. By incorporating the data in Table A-1, a table similar to Table A-2 can then be constructed for each individual facility by using the following equations. (All tables appear at the end of the text.)

Capital cost per emission source: (No. of components) x (capital cost per component)

Total capital cost per plant: Σ [capital cost per emission source]

Annual cost per emission source: (No. of components) x (annual cost per component)

Total annual cost per plant: Σ [annual cost per emission source]

EDC emission reduction per emission source: (current EDC emission) x (percent reduction)

Total EDC emission reduction per plant: Σ [EDC emission reduction per emission source]

VOC emission reduction per emission source: (current VOC emission) x (percent reduction)

Total VOC emission reduction per plant: Σ [VOC emission reduction per emission source]

EDC recovery credits per emission source: (EDC emission reduction per emission source) x (1st Quarter 1984 EDC market value ($326/Mg))

Total EDC recovery credit per plant: (Total EDC emission reduction per plant) x (1st Quarter 1984 EDC market value ($326/Mg))

VOC recovery credit per emission source: (VOC emission reduction per plant) x (1st Quarter 1984 EDC market value ($326/Mg)).

VOC recovery credit per plant: (VOC emission reduction per plant) x (1st Quarter 1984 EDC market value ($326/Mg)).

Net annual cost (EDC) per emission source: (annual cost per emission source) minus (EDC recovery credits per emission source).

Net annual cost (EDC) per plant: (total annual cost per plant) minus (total EDC recovery credits per plant).

Net annual cost (VOC) per emission source: (annual cost per emission source) minus (VOC recovery credits per emission source).

Net annual cost (VOC) per plant: (total annual cost per plant) minus (total VOC recovery credits per plant).

Cost effectiveness for controlling EDC emissions per emission source: (net annual cost (EDC) per emission source) per (EDC emission reduction per emission source).

Cost effectiveness for controlling EDC emissions per plant: (net annual cost (EDC) per plant) per (EDC emission reduction per plant).

Cost effectiveness for controlling VOC emissions per emission source: (net annual cost (VOC) per emission source) per (VOC emission reduction per emission source).

Cost effectiveness for controlling VOC emissions per plant: (net annual cost (VOC) per plant) per (VOC emission reduction per plant).

COST CONVERSION CALCULATIONS

CE Plant Cost Index (Chemical Engineering June 11, 1984)

Updating May 1979 dollars to March 1984 dollars.

CE Plant Cost Index.

Fabricated equipment = March 1984 = \$332.9
Mid 1979 = \$238.7

$$\frac{332.9}{238.7} = 1.395$$

Conversion of EDC cost from mid-1982 dollars to 1st Quarter 1984 dollars:

M&S Equipment Cost Index (Chemical Engineering June 11, 1984)

Chemical products 1st Quarter 1984 = 783.6
Annual index mid-1982 = 745.6

Conversion factor for converting mid-1982 dollars to 1st Quarter 1984 dollars:

$$\frac{783.6}{745.6} = 1.05$$

EDC value/Mg = (\$310)(1.05) = 326/Mg
1st Quarter 1984

SECTION A-2: SAMPLE COST CALCULATIONS FOR INSTALLING INTERNAL FLOATING ROOFS IN FIXED ROOF TANKS

The following equations are used to calculate the capital and annualized cost for the installation of a mild steel welded contact internal floating roof to a fixed roof storage tank.[1] This internal floating roof utilizes both primary (constructed of Teflon®) and secondary (constructed of Viton®) seals. An example calculation is also attached demonstrating these equations.

A. Capital Cost (4th Quarter 1982 Dollars)

1. Degassing Cost[2]

Cost = $\$130.8\ V^{0.5132}$ or \$1,000, whichever is greater where V = tank volume in cubic meters.

2. Estimated Installation Cost[3]

a. Basic cost of roof and primary seal:

$$\text{Cost} = (1.91 + 2.54 \times D) \times \$1{,}000 + (\$204 \times D)$$

D = tank diameter in meters

(The \$204 x D cost reflects the additional cost of using Teflon® coated fiberglass versus the standard polyurethane coating.)[4]

b. Additional cost of adding secondary seal:[5]

$$\text{Cost} = \$580 \times D$$

(The \$580 x D cost reflects using a Viton® coated material for the secondary seal.)

3. Door Sheet Opening Cost[6]

Cost = \$1,300

Total capital cost (primary seal) = degassing cost + estimated installed cost (2a) + door sheet opening cost.

Total capital cost (primary + secondary seals) = degassing costs + estimated installed cost (2a,b) + door sheet opening cost.

B. Annual Cost[7] (4th Quarter 1982 Dollars)

1. Tax, insurance, and administration--4% of capital cost (based on 10 percent interest rate and 10 year equipment life)
2. Maintenance--5% of capital cost
3. Inspection--1% of capital cost
4. Capital recovery factor--16.275% of capital cost

Total annual cost = [26.275% of capital cost]

C. EDC Emission Reduction

1. Internal floating roof primary seal[8]

(0.94)(current EDC emissions (Mg))

2. Internal floating roof primary + secondary seals[9]

(0.97)(current EDC emissions (Mg))

D. EDC Recovery Credits (1st Quarter 1984 Dollars)

Credits = ($326)(EDC emissions reduced)

E. Net Annual Cost

(Before annual cost can be calculated, all costing data is converted to 1984 dollars using Chemical Engineering Economic Indicators.)

Cost = annual cost (1st quarter 1984 dollars) - EDC recovery credits (1st Quarter 1984 dollars)

F. Cost Effectiveness

= net annual cost/EDC emission reduction (Mg)

G. Cost Conversion Calculations

Convert equipment cost from 4th Quarter 1982 dollars to 1st Quarter 1984 dollars

CE Plant Cost Index[10]

Fabricated equipment 1st Quarter 1984 = 332.9

$$\begin{array}{rl} \text{Annual index 1983 (mid)} = & 316.9 \\ \text{1982 (mid)} = & \underline{314.0} \\ & 2.9 \end{array}$$

Average increase per quarter = 2.9/4 = 0.725

4th Quarter 1982 = 314 + (2)(0.725) = 315.45

Conversion factor for converting 4th Quarter 1982 dollars to 1st Quarter 1984 dollars =

$$\frac{332.9}{315.45} = 1.0553$$

Conversion of EDC cost from mid-1982 dollars to 1st Quarter 1984 dollars:

M&S Equipment Cost Index[10]

Chemical products 1st Quarter 1984 = 783.6
Annual index mid-1982 = 745.6

Conversion factor for converting mid-1982 dollars to 1st Quarter 1984 dollars:

$$\frac{783.6}{745.6} = 1.05$$

EDC value/Mg[11] = ($310)(1.05) = $326/Mg
1st Quarter 1984

H. Example Storage Tank Calculations

Data[12]

$D = 31.7$ m
$V = 9{,}620$ m^3
Current emissions = 29.42 Mg/yr

Capital Cost (4th Quarter 1982 Dollars)

1. Degassing cost

   $\text{Cost} = \$130.8\ (9{,}620^{0.5132}) = \$14{,}480$

2. Estimated installation cost

   a. Primary seal only

      Cost = (1.91 + 2.54 x 31.7) x $1,000 + ($204 x 31.7) = $88,895

   b. Primary + Secondary seal additional cost

      Cost = $580 x 31.7 = $18,386

3. Door sheet opening cost

Cost = $1,300

Total capital cost (primary seal)

Cost = $14,480 + 88,895 + 1,300 = $104,675

Total capital cost (primary + secondary seal)

Cost = $14,480 + 88,895 + 18,386 + 1,300 = $123,061

Annual cost (primary seal only)

Cost = 0.26275($104,675) = $27,503

Annual cost (primary + secondary seals)

Cost = 0.26275($123,061) = $32,334

Conversion of capital and annual cost data to 1st Quarter 1984 dollars

Capital cost (primary seal only) = ($104,675)(1.0553) = $110,464

Capital cost (primary + secondary seals) = ($123,061)(1.0553) = $129,866

Annual cost (primary seal only) = ($27,503)(1.0553) = $29,024

Annual cost (primary + secondary seals) = ($32,334)(1.0553) = $34,122

EDC Emissions Reduced

1. (Primary seal only) = (0.94)(29.42 Mg/yr) = 27.65 Mg/yr
2. (Primary + secondary seals) = (0.97)(29.42 Mg/yr) = 28.54 Mg/yr

EDC Recovery Credits (1st Quarter 1984 Dollars)

1. (Primary seal only) credits = ($350)(27.65) = $9,678
2. (Primary + secondary seals) credits = ($350)(28.53) = $9,986

Net Annual Cost (1st Quarter 1984 Dollars)

1. (Primary seal only) = $29,024 - 9,678 = $19,346
2. (Primary + secondary seals) = $34,122 - 9,986 = $24,136

Cost Effectiveness

1. (Primary seal only) = $19,346 ÷ 27.65 = $700/Mg
2. (Primary + secondary seal) = $24,136 ÷ 28.54 = $846/Mg

SECTION A-3: SAMPLE COST CALCULATIONS FOR CONDENSER SYSTEMS (Storage tanks and process vents)

This section presents assumptions and sample calculations for determining the filling rate, capital and annualized costs, recovery credits, and emissions reduction for condenser control systems controlling emissions from EDC storage tanks. The condenser system has an efficiency of 95 percent.

Estimates of EDC emissions and the size specifications for storage tanks were reported by each company in its response to EPA's information request. The following correlations were determined from the information request concerning tank size versus filling rate and gas flow rate to condenser.

Tank volume (m^3)	Filling rate (gpm)	Gas flow rate to condenser (acfm)
1-5	100	13.37
6-100	200	26.74
>100	2,000	267.40

The gas flow rates presented above are used to determine the capital and annualized costs for each condenser system. Capital cost estimates represent the total installed capital costs for the condenser system and its refrigeration unit. The methodology for determining capital and annualized costs is presented in Organic Chemical Manufacturing Volume 5: Adsorption, Condensation, and Absorption Devices.[13] These costs are presented in graph form in Figures A-3.1 and A-3.2.

To determine the percentage VOC in the emission stream the following methodology was used.

Average storage tank temperature = 77°F
At 77°F (EDC) partial pressure = 1.63 psia

Atmospheric pressure = 1 atm = 14.69 psia

% VOC in emission stream $= \frac{1.63}{14.69} = 11\%$

Therefore, to determine capital and annual cost each gas stream is assumed to contain 10 percent VOC.

The following equations are used to approximate the capital and annual cost for annual filling rates of less than 100 acfm.

Capital cost = 277.5 [filling rate (acfm)] + 3.15 $\times 10^4$
Annual cost = 70 [filling rate (acfm)] + 2.30 $\times 10^4$

The equations for capital and annualized costs for EDC storage tanks with filling rates of less than 100 acfm were obtained by calculating equations of the 10 percent VOC lines on Figures A-3.1 and A-3.2. The annual average filling rate is calculated by the following.

Annual average filling rate = (filling rate per tank)(A/B)

$$A = \left(\frac{1}{\text{filling rate per tank}}\right)(\text{tank volume})(N) = \text{minutes of tank filling}$$

N = number of times the tank is filled per year

$$= \left(\frac{\text{annual throughput}}{\text{tank volume}}\right)$$

B = minutes per year of tank operation

= 525,600 minutes/yr (based on 24 h/d and 365 d/yr of operation)

For a tank volume of 128.44 m^3 (4,536.5 ft^3) and a throughput of 11,250 m^3 (397,350 ft^3), the annual average filling rate is calculated below.

$$\text{Average annual filling rate} = \frac{(267.4\ \text{acfm})\left(\frac{1}{267.4\ \text{acfm}}\right)(4{,}537\ \text{ft}^3)\left(\frac{397{,}350\ \text{ft}^3}{4{,}537\ \text{ft}^3}\right)}{525{,}600\ \text{min/yr}} = 0.76\ \text{acfm/yr}$$

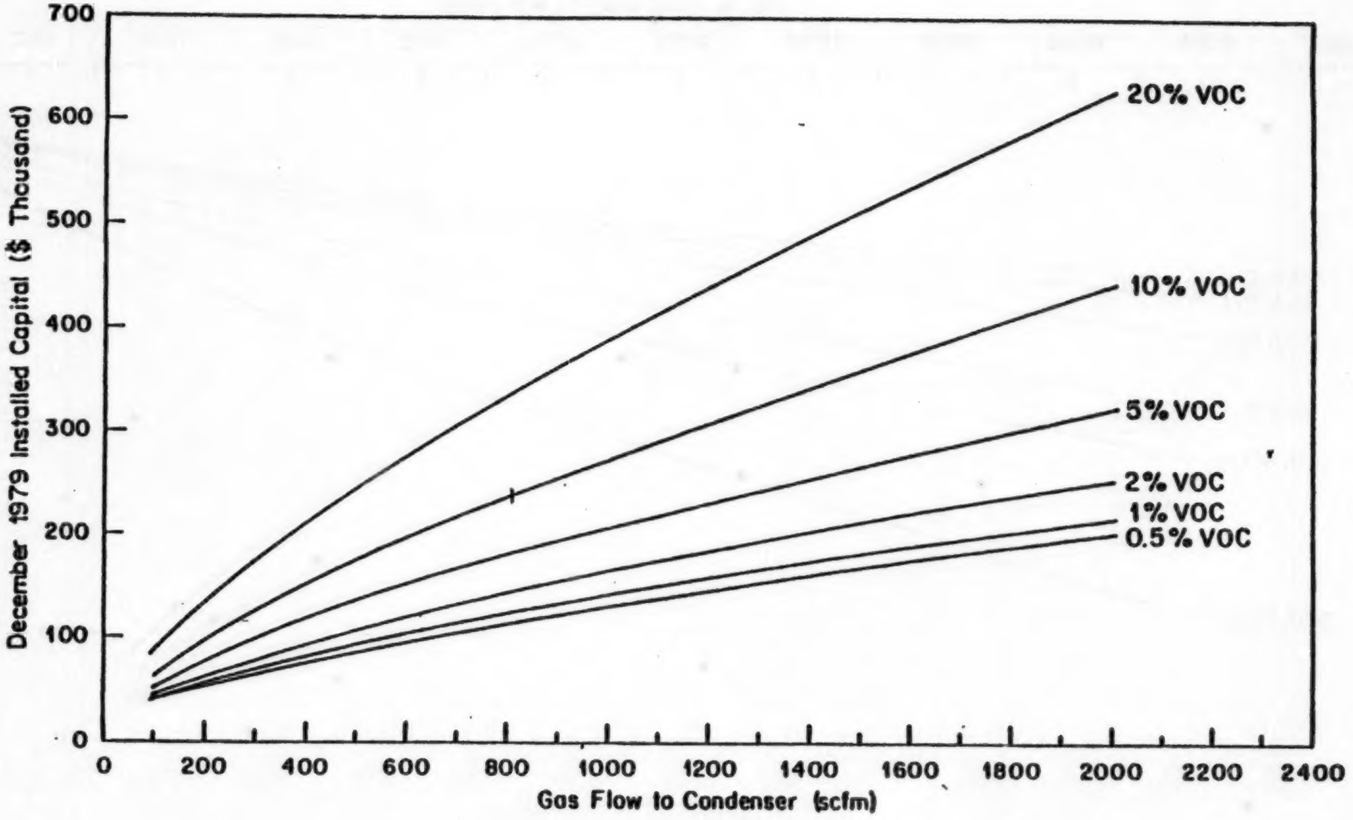

Figure A-3.1. Installed capital cost vs flow rate for complete condenser system with a VOC removal efficiency of 95 percent.[14]

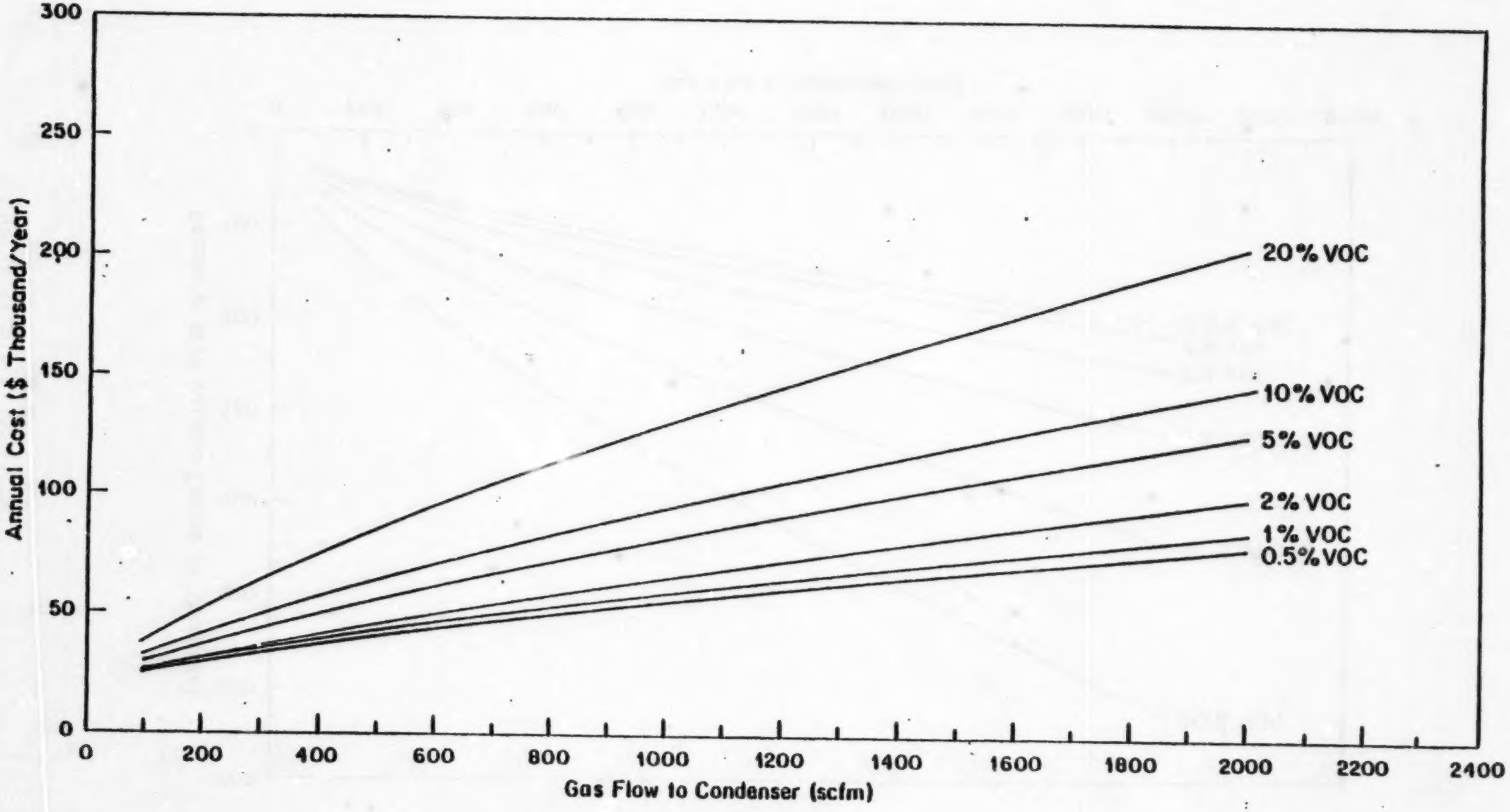

Figure A-3.2. Annual cost vs flow rate for complete condenser system with VOC removal efficiency of 95 percent and no VOC recovery credit.[15]

SECTION A-4: SAMPLE CALCULATIONS FOR SHIPPING COSTS

Data

Barges/yr = 81[16]

Filling time = 2.5-3 h[16]

Emissions = 188 Mg/yr[17]

Control efficiency = 98% (See Cost Efficiency Calculations)

EDC value/Mg = 310 $/Mg[18] mid-1982 dollars

EDC value/Mg = 326 $/Mg, 1st Quarter 1984, dollars
(See Cost Conversion Calculations)

Control Efficiency Calculation

Standard temperature of tank = 77°F

Partial pressure = 84.30 mm Hg

Refrigerated temperature = -99.4°F
Partial press ~1 mm Hg

Atmospheric pressure 760 mm Hg
1 - [(1/760)/(84.3/760)] = 1 - 0.02 = 98%

Control efficiency = 98%

Cost Conversion Calculations

Convert equipment cost (1979 dollars to 1984 dollars):

CE plant cost index[19]
Fabricated equipment 1st Quarter 1984 = 332.9
Annual index: 1980 (mid) = 261.2
1979 (mid) = 238.7
22.5

Average increase per quarter = 22.5/4 = 5.625

4th Quarter 1979 = 238.7 + (2)(5.625) = 249.95

Conversion factor for converting 4th Quarter 1979 dollars to 1st Quarter 1984 dollars =

$$\frac{332.9}{249.95} = 1.332$$

For the conversion of EDC cost from mid-1982 to 1st Quarter 1984 dollars, use the following procedure:

M&S Equipment Cost Index[19]

Chemical products 1st Quarter 1984 = 783.6
Annual index mid-1982 = 745.6

Conversion factor for converting mid-1982 dollars to 1st Quarter 1984 dollars =

$$\left(\frac{783.6}{745.6}\right) = 1.05$$

EDC Value/Mg = ($310)(1.05) = $326 1st Quarter 1984 dollars.

The following data is an example of the calculations necessary to analyze the installation cost of a refrigeration unit to control shipping emissions. The fixed capital cost is for an average refrigeration unit of a size that could handle consecutive barge loading indefinitely with 1 to 2 hours lapse time between each loading.[20] This fixed capital cost is used for all shipping emissions costing.

REFERIGERATION UNIT (1979 4th Quarter Dollars)[21]

Fixed capital

Skid mounted unit	$264,600
Concrete pad	2,700
Electric feeder	5,000
Freight	3,000
Rigging, crane, and men at $175 for 8 h	1,400
Vapor piping to unit	10,000
Parts inventory	6,000
	$292,700

Capital recovery cost (CRC)

$$\text{CRC} = (\text{fixed capital costs}) \times \frac{i(1+i)^n}{(1+i)^n - 1}$$

where i = annual interest rate
n = capital recovery period

CRC for 10 percent annual interest rate and 15 years equipment life = 0.131

CRC = (0.131)x(292,700) = 38,340

Electricity

140 kWh x 3.0 h (load) = 420
442 kWh x \$0.06/kWh x 81 barges/yr = \$2,148

Maintenance and operating labor

Based on \$15/h and 1,000 h = \$15,000

General and administrative

15 percent of other yearly operating costs
(0.15)(55,900) = \$8,400
Annual cost = \$55,900 + \$8,400 = \$64,300/yr

REFRIGERATION UNIT (1984 1st Quarter Dollars)
(Refer to Cost Conversion Calculations)

Fixed capital = \$292,700 (1.332) = \$389,900
Annual cost = (\$64,300)(1.332) = \$85,650
Mg EDC reduced = (EDC emissions)(control efficiency)
= (188)(0.98) = 184 Mg

EDC recovery credits = (Mg EDC reduced)(EDC value/Mg)
= (184)(\$326) = \$60,000

Net annual cost = [annual cost]-[EDC recovery credit]
= \$85,650 - \$60,000 = \$25,650

$$\text{Cost effectiveness} = \frac{\text{Net annual cost}}{\text{Mg EDC reduced}}$$

$$= \frac{\$25{,}650}{184} = \$140/\text{Mg}$$

SECTION A-5: SAMPLE COST CALCULATIONS FOR CONTROL OF PROCESS EMISSIONS COSTS

This section presents data and calculations necessary for determining the capital costs, annual costs, and cost effectiveness of thermal incineration systems used to control EDC process emissions. The total installed capital cost is a function of the process offgas flowrate and is calculated from the following equation.[22]

$$\text{Total Installed Capital Cost (\$1,000)} = \text{(No. of units)} \times \text{(Escalation Factor)} \times (C_1 + C_2\,[\text{Flowrate (NM}^3\text{/min)} \div \text{Design Vent Size Factor}]^{C_3}$$

The gas flowrate is 10,667 acfm (302.1 m^3/min) and is reported by the company to contain no moisture at 28°C (82°F). Therefore, the gas flowrate equals 10,583 dscfm (294.1 Nm^3/min) when corrected to standard conditions. The selection of the incinerator design category was based on offgas net heating value, the design flowrate, and the presence or absence of halogenated compounds. Categories A1 and A2 were selected because EDC is a halogenated compound and all factors used in the above equation are based on process vent streams containing halogenated compounds. For these sample calculations, the total installed capital costs are based on a gas flowrate of 10,383 dscfm (294.1 m^3/min) and equal $2,985,000.

Tables A-3, A-4, A-5, and A-6 show cost factors, operating factors, and cost equations for calculating annualized costs for the thermal incineration system. The process is assumed to operate 24 h/day and 350 days/yr (8,400 h/yr), and the control device operating labor is 2,400 h/yr. The calculations and rates for operating labor, electricity, natural gas, heat recovery credit, quench water, scrubbing water, and caustic are presented below. The maintenance labor plus materials factor is 0.06 of total installed capital cost and the overall taxes and maintenance factor is 0.11 of total installed capital cost.[22]

Annualized Costs (based on 2,400 h/yr of operation)

Direct

- Operating Labor ($13.08/h):
  ($13.08/h)(2,400 h/yr) = $31,000/yr

- Electricity ($0.02616/kwh):
  (0.0604)($0.02616/kwh)(22 in. w.c.)(294.1 Nm^3/min)(2.9)
  = $30,000/yr

- Natural Gas ($4.78/thousand MJ):
  Natural gas used:
  0.504 million min/yr x G0 + flowrate x (G1 + G2 x heating value
  + G3 x heating value^2)

  (0.504)(0) + (294.1) [4.86 + (-0.985)(3.5) + (0)$(3.5)^2$]
  = 415.42 TJ/yr

- Natural gas cost ($4.78/GJ):
  ($4.78/GJ)(415.42 TJ/yr) $1,986,000

- Heat Recovery Credit ($4.78/GJ):
  ($4.78/GJ)(3.63 MJ/Nm^3)(294.1 Nm^3/min)(0.504 million min/yr)
  = $2,572,000/yr

- Quench Water ($0.22/thousand gallons)
  ($0.22/thousand gallons)(294.1 Nm^3/min) (0.00886)(2.9) = $2,000/yr

- Scrubbing Water ($0.22/thousand gallons)
  ($0.22/thousand gallons)(294.1 Nm^3/min)(0.289)(2.9) = $54,000/yr

- Caustic ($0.0436/lb):
  ($0.0436/lb)(294.1 Nm^3/min)(17.17)(2.9) = $638,000/yr

- Maintenance Labor plus Materials Factor (0.06 of total installed capital cost):
  (0.06)($2,995,000) = $179,000/yr

- Overall Taxes and Maintenance Factor (0.11 of total installed capital cost):
  (0.11)($2,985,000) = $328,000/yr

Indirect

Interest rate (i) = 8.5% (after taxes)
= 10% (before taxes)
Incinerator Lifetime (N) = 10 years

$$\text{Capital Recovery Factor} = \frac{i(1 + i)^N}{(1 + i)^N - 1} \begin{array}{l} = 0.152 \text{ (after taxes)} \\ = 0.163 \text{ (before taxes)} \end{array}$$

Taxes, Insurance, and Administrative Charges Factor = 0.05 of total installed capital cost.

Overall Capital Charges Factor = 0.213 of total installed capital cost.

Operating cost = Taxes and Maintenance Cost per unit + (No. of units) (gas cost + labor cost + electricity cost + quench water cost + scrubber water cost + caustic cost - heat recovery credit)

OC = \$328,000 + (1)(1,986,000 + 31,000 + 30,000 + 2,000 + 54,000 + 638,000 - 2,572,000) = \$497,000

Annualized costs = OC + (Capital Recovery Factor)(Capital Costs)
= \$497,000 + (0.163)(\$2,985,000)
= \$984,000 (before taxes)

The annualized costs of \$984,000 are calculated in December 1979 dollars and are updated to March 1984 dollars using the Chemical Engineering Plant Cost Index for Fabricated Equipment. The fabricated equipment cost factor is used to simplify the updating of the capital and annualized costs.

Annualized costs (March 1984) = \$984,000 (Dec. 1979) $\left[\frac{332.9}{218.8}\right]$

= \$1,497,000

Annual emissions w/existing emission control

= 3,977 kg/yr

Annual emissions reduction w/incinerator

= (3,977 kg/yr)(0.98)
= 3,897 kg/yr (3.9 Mg/yr)

Cost effectiveness = \$1,497,000 ÷ 3.0 Mg/yr
= \$383,846/Mg (before taxes)

TABLE A-1. CONTROL TECHNIQUES AND COST FOR VOC/EDC FUGITIVE EMISSION SOURCES[a]
1984 Dollars

Equipment type (emission source)	Control techniques	Percent reduction	Capital cost, $/component[b]	Annualized cost, $/component[b]
1. Pump seals				
· Packed	Monthly inspection	83.3	0	370
· Mechanical	Monthly inspection	83.3	0	370
· Double mechanical[d]	N/A[e]	N/A	N/A	N/A
2. Compressors	Degassing Reservoir vents	100	10,200	2,580
3. Flanges	None Available	N/A	N/A	N/A
4. Valves				
· Gas	Monthly inspection	70.3	0	20
· Liquid	Monthly inspection	72.5	0	20
5. Pressure relief devices				
· Gas	O-Ring	100	310	80
· Liquid[d]	N/A	N/A	N/A	N/A
6. Sample connections				
· Gas	Closed-purge sampling systems	100	670	170
· Liquid	Closed-purge sampling systems	100	670	170
7. Open ended lines				
· Gas	Caps on open ends	100	70	20
· Liquid	Caps on open ends	100	70	20

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[a] Reference No. 23.

[b] Dollars updated using CE Plant Cost Index and M&S Equipment Cost Index (Chemical Engineering, June 11, 1984).

[c] Based on 10-year equipment life and 10 percent interest (CRF = 0.163).

[d] Assume 0 emissions per year.

[e] N/A = Not applicable.

TABLE A-2. FUGITIVE EMISSIONS CONTROL COST CALCULATIONS[a]
(First Quater 1984 Dollar)

Emission source	No. of components[b]	Capital cost/ compo- nent, $[c]	Annual cost/ compo- nent, $[c]	Capital cost per emission source[e]	Annual cost per emission source[e]	Current EDC emissions, Mg/yr[f]	Current VOC emissions, Mg/yr	Percent emission reduction
Pumps	1	0	370	0	370	0.22	0.5	83.3
Compressor	1	10,200	2,580	10,200	2,600	2.0	2.0	100
Valves, (gas)	85	0	20	0	1,700	2.8	4.0	70.3
Valves, (liquid)	142	0	20	0	2,800	6.2	9.0	12.5
Pressure relief	6	310	80	1,900	500	3.0	5.5	100
Sample connect	26	670	170	17,400	4,400	2.1	3.3	100
Open ends	0	70	20	0	0	0	0	100
Flanges	--	--	--	--	--	3.5	5.1	N/A
Totals	N/A	N/A	N/A	29,500	12,400	20	29	N/A

TABLE A-2. (continued)

Emission source	EDC emission reduction, Mg	VOC emission reduction, Mg	EDC recovery credit, $[j]	VOC recovery credit, $[k]	Net annualized cost EDC, $[l]	Net annualized cost VOC, $[m]	Cost effectiveness EDC, $/kg	Cost effectiveness VOC, $/kg
Pumps	0.18	0.42	60	150	300	220	1,700	520
Compressor	2.0	2.00	650	650	1,950	1,950	980	980
Valves, (gas)	2.0	2.8	650	910	1,100	800	600	290
Valves, (liquid)	4.50	6.5	1,500	2,150	1,300	650	290	100
Pressure relief	3.0	5.5	1,000	1,800	-500	-1,300	-170	-240
Sample connect	2.1	3.3	700	1,100	3,700	3,300	1,800	1,000
Open ends	--	--	--	--	--	--	--	--
Flanges	--	--	--	--	--	--	--	--
Totals	14	21	4,600	6,800	7,800	5,600	560	270

[a] Calculated using CE Plant Cost Index and M&S Equipment Cost Index (Chemical Engineering, June 11, 1984).

[b] No. of components cited from Section 114 information request responses.

[c] Cost for each component taken from Publication No. EPA 450/3-80-0326, Benzene Fugitive Emissions--Background Information for Promulgated Standards, Tables A-1 through A-9.

[d] Capital cost/component x No. of components.

[e] Annual cost/component x No. of components.

[f] Emission data based upon information request responses.

[g] Reduction efficiency from Publication No. EPA 450/3-80-0326 Benzene Fugitive Emissions--Background Information for Promulgated Standards, Tables A-1 through A-9.

[h] Current EDC emissions x emission reduction efficiency.

[i] Current VOC emissions x emission reduction efficiency.

[j] $350 x EDC emission reduction.

[k] $350 x VOC emission reduction.

[l] Total annualized cost - EDC recovery credit.

[m] Total annualized cost - VOC recovery credit.

TABLE A-3. TOTAL INSTALLED CAPITAL COST FOR INCINERATORS AS A FUNCTION OF OFFGAS FLOWRATE[a]

Maximum flowrate per unit (thousand Nm^3/min)	Fabricated equipment cost escalation factor	Design vent size factor	C1	C2	C3
0.74	0.900	0.95	802.70	16.16[b]	0.88

Total installed capital cost (\$1,000) = (No. of units) x (escalation factor) x (C_1 + C_2 [flowrate (Nm^3/min) ÷ design vent size factor]^{C_3})[c]

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[a] Reference No. 22.

[b] Flowrate correction factor of 1.12 = $(1.14)^{.88}$ incorporated into coefficient C2.

[c] Flowrate per equipment unit.

TABLE A-4. ANNUALIZED COST FACTORS FOR INCINERATORS[a]

December 1978 dollars

Direct

Operating labor: \$13.08/h (includes overhead)[b]

Operating labor factor: 2,400 labor-h/yr (categories A1-A2)
2,133 labor-h/yr (categories B-C)
1,200 labor/h/yr (categories D - E)

Electricity: \$0.02616/kWh[b]

Natural gas: \$4.78/thousand MJ[e]

Heat recovery credit: \$4.78/thousand MJ

Quench water price: \$0.22/thousand gallons[b]

Scrubbing water price: \$0.22/thousand gallons[b]

Caustic price: \$0.0436/lb[b]

Maintenance labor plus materials factor = 0.06 of total installed capital

Indirect ("capital charges")

Interest rate = i = 8.5% (after taxes)[c]
= 10% (before taxes)

Incinerator lifetime = 10 years = N

Capital recovery factor = $\frac{i\,(1+i)^N}{(1+i)^N-1}$ = 0.152 (after taxes)[c]
= 0.163 (before taxes)[d]

Taxes, insurance, and administrative charges factor = 0.05 of total installed capital

Overall capital charges factor = 0.213 of total installed capital

Overall taxes and maintenance factor = 0.11 of total installed capital

---

[a] Reference No. 22.
[b] Corrected from Enviroscience values (in December 1979 dollars) to December 1978 dollars by a deflation factor of 0.872.
[c] After tax interest rate and capital recovery factor used in process-specific economic analysis and calculating typical costs for facilities in each design category.
[d] Before tax interest rate and capital recovery factor used in calculating national cost impact for each regulatory alternative.
[e] Galloway, J., EEA telecon with Robson, J., EPA:EAB, July 13, 1981. Discussion on natural gas prices.

TABLE A-5. OPERATING FACTORS FOR INCINERATORS

Minimum net heating value (MJ/Nm³)	Maximum net heating value (MJ/Nm³)	Ratio of flue gas flow to offgas flow[a]	Minimum heat recovered (MJ/Nm³)	Pressure drop (inches H_2O)	Labor cost ($1,000/yr)	Natural gas use coefficients			
						G0	G1	G2	G3
0	3.5	2.9	3.63	22[c]	31.39	0	4.86	-0.985	0

---

[a] Both at standard conditions.

[b] Includes 6 inches across the combustion chamber, 4 inches across the waste heat boiler, and 12 inches across the scrubber.

TABLE A-6. ANNUALIZED COST EQUATIONS FOR INCINERATORS

Operating flowrate (Nm^3/min) = design flowrate (Nm^3/min) x capacity utilization factor

In the following operating cost and emissions equations, "flowrate" means the operating flowrate per equipment unit (dilution flowrate for Category E)

Natural gas used (TJ/yr) = 0.5256 million min/yr x G0 + flowrate x (G1 + G2 x heating value + G3 x heating value^2)

Natural gas cost ($1,000/yr) = natural gas price ($/GJ) x natural gas used (TJ/yr)

Labor cost ($1,000/yr) = labor wage ($/man-h) x operating labor factor (man-h/yr) ÷ 1,000

Electricity cost ($1,000/yr) = 0.0604 x electricity price ($/kWh) x pressure drop (inches H_2O) x flowrate (Nm^3/min) x flue-gas/offgas ratio

Quench water cost ($1,000/yr) = quench water price ($/thousand gal) x flowrate (Nm^3/min) x 0.00886 x flue-gas/offgas ratio

Scrubbing water cost ($1,000/yr) = scrubbing water price ($/thousand gal) x flowrate (Nm^3/min) x 0.289 x flue-gas/offgas ratio

Caustic cost ($1,000/yr) = caustic price ($/lb) x flowrate ($Nm^3$/min) x 17.17 x flue-gas/offgas ratio

Heat recovery credit ($1,000/yr) = natural gas price ($/GJ) x heat recovery factor (MJ/Nm^3) x flowrate (Nm^3/min) x 0.5256 (million min/yr)

Taxes and maintenance cost ($1,000/yr) = installed capital ($1,000) x taxes and maintenance factor

Operating cost ($1,000/yr) = taxes and maintenance cost ($1,000/yr) + number of equipment units x (gas cost + labor cost + electricity cost
+ quench cost + scrub cost + caustic cost
- heat recovery credit)

Annualized cost ($1,000/yr) = operating cost + capital recovery factor x capital cost ($1,000)

Hourly emissions (kg/h) = 0.0268 (moles/Nm^3)(min/hour)(kg/g)(1/100%) x flow (Nm^3/min) x (% VOC) x (molecular weight)

Annual emissions (Gg/yr) = hourly emissions (kg/h) x 365 days/year x 24 hours/day x 1 Gg/10^6kg

Annual emission reduction (Gg/yr) = annual emission (Gg/yr) x 0.98

Cost effectiveness ($/Mg) = annualized cost ($1,000/yr) ÷ annual emission reduction (Gg/yr)

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APPENDIX B

EXISTING STATE REGULATIONS

The regulations to control EDC emissions vary between the six States (Texas, Kansas, New Jersey, California, Louisiana, Kentucky) where EDC and EDC products are produced.[1] Of these six States, only California has no regulations that would control EDC emissions. New Jersey regulates EDC emissions under its toxic air volatile organic substances (TVOS) regulations. Other States either do not control certain sources or regulate them under their general volatile organic compound (VOC) regulations.

In New Jersey, emissions of EDC from production processes, storage tanks, or transfer operations are prohibited unless the equipment and operation are registered with the New Jersey Department of Environmental Protection. The control of EDC emissions from the equipment or operating processes is to represent advances in the art of control as determined by the New Jersey Department of Environmental Protection. The discharge of any TVOS into the atmosphere must be:

1. No less than 12.2 meters (m) (40 feet [ft]) above grade;
2. No less than 6.1 m (20 ft) higher than any area of human use of occupancy within 15.2 m (50 ft); and
3. Directed vertically upward at a velocity of 1,097 meters per minute (m/min) (3,600 feet per minute [fpm]).

Also, any discharge of TVOS into the atmosphere from a system, equipment, or control device must be effective in preventing aerodynamic downwash.

Ethylene dichloride emissions from a production process of EDC are not controlled under any Texas, Kansas, or Kentucky regulations. Louisiana regulates EDC emissions under its volatile organic compound (VOC) regulations. If a facility emits greater than 1.4 kilograms per hour (kg/h) (3.0 pounds per hour [lb/h]) or 6.8 kg/d (15 lb/d) of VOC, it must reduce the emissions either by incineration (90 percent removal efficiency required) or by using a carbon adsorption system. With any process upsets, start-ups, or shutdowns, VOC emissions must be vented and reduced either by an afterburner, carbon adsorption system, refrigeration, catalytic and/or thermal reaction, secondary steam stripping, recycling, or vapor recovery system.

Regulations pertaining to storage tanks laden with materials emitting VOC emissions are quite similar between Texas, Kansas, Louisiana, and Kentucky with only minor variations in allowed pressure levels and tank storage size associated with different control techniques. In general, a storage tank with a capacity greater than 151,400 liters (ℓ) (40,000 gallons [gal]) but having less than 76 kilopascals (kPa) (11 pounds per square inch absolute [psia]) of pressure, would require a floating roof with seals between the tank wall and roof edge, or a vapor recovery system which returns vapor to a disposal system. For tanks smaller than 151,400 ℓ (40,000 gallons), a submerged fill pipe is considered sufficient control, and for tanks larger than 151,400 ℓ (40,000 gallons) with pressure greater than 76 kPa (11 psia), a submerged fill pipe and vapor recovery system is required.

Kentucky and Kansas do not have any regulations concerning loading and unloading of materials emitting VOC emissions. In Louisiana, facilities with at least 75,700 ℓ (20,000 gallons) of throughput per day must have vapor collection and disposal systems. All pumps and compressors handling VOC's should also be equipped with mechanical seals.

In Texas attainment and nonattainment areas, facilities with at least 75,700 ℓ (20,000 gallons) of throughput per day are required to have vapor tight seals and vapor collecting or recovery system to pick up residual emissions at loading and unloading operations. In nonattainment areas, the vapor recovery system should ensure that VOC emissions are reduced to a level not to exceed 0.08 kg (0.17 pounds) of VOC per 3,785 ℓ (1,000 gallons) of liquid transferred. In Harris County, with facilities of 1.9 x10^6 ℓ (500,000 gallons) of throughput a day, reduction of VOC emissions must be down to a level of 0.15 kg (0.33 pounds) per 3,785 ℓ (1,000 gallons) transferred.

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